UNIVERSIDADE DE LISBOA

Faculdade de Medicina Veterinária

EXTRA - ARTICULAR ILIOFEMORAL SUTURE PLACEMENT WITH BONE ANCHORS – SURGICAL OPTION FOR RESOLUTION OF CRANIODORSAL COXOFEMORAL LUXATIONS IN DOGS

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DISSERTAÇÃO DE MESTRADO INTEGRADO EM MEDICINA VETERINÁRIA

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To my family, for all the dedication, unconditional love and support.
Without you, I wouldn't be the person I am today.

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ABSTRACT

EXTRA - ARTICULAR ILIOFEMORAL SUTURE PLACEMENT WITH BONE ANCHORS – SURGICAL OPTION FOR RESOLUTION OF CRANIODORSAL COXOFEMORAL LUXATIONS IN DOGS

Coxofemoral luxations are a common traumatic injury seen in small animal practice, representing up to 90% of all luxations in dogs and cats.

Despite the variety of surgical techniques available for the management of this condition, none seem to be ideal, as almost every surgical procedure has complications and drawbacks associated with it. However, extra-articular techniques have been described in order to avoid potential complications and studies have reported good or excellent clinical results with low rates of complications.

In this study, we described and evaluated a modification of the extra-articular iliofemoral suture placement technique, originally described by Slocum and Devine (1987), through the application of two bone anchors and a crimping system, and reported complications associated with the procedure.

The study sample comprised 7 dogs and a minimum of 4 weeks follow-up period was required. The overall complication rate was 29% (2/7), including surgical wound infection and reluxation.

The results of this study suggest that the extra-articular iliofemoral suture with bone anchors appears to be an effective surgical technique for the treatment of craniodorsal coxofemoral luxations, but further research is necessary to investigate the factors associated with patient selection that might justify some of the postoperative complications identified.

Keywords: Luxation, coxofemoral joint, craniodorsal, iliofemoral suture, bone anchor, crimping system

RESUMO

COLOCAÇÃO DE UMA SUTURA EXTRA - ARTICULAR ILEOFEMORAL COM ÂNCORAS ÓSSEAS – OPÇÃO CIRÚRGICA PARA A RESOLUÇÃO DE LUXAÇÕES COXOFEMORAIS CRANIODORSAIS EM CÃES

As luxações coxofemorais são uma lesão frequente em clínica de animais de companhia, representando até 90% de todas as luxações que ocorrem em cães e gatos.

Apesar da variedade de técnicas cirúrgicas disponíveis para a sua resolução, nenhuma parece ideal, pois quase todos os procedimentos cirúrgicos apresentam complicações e inconvenientes associados. Encontram-se descritas técnicas extra-articulares que visam evitar potenciais complicações e estudos demonstram bons a excelentes resultados com uma taxa de complicações baixa.

Neste estudo descrevemos e avaliámos uma modificação da técnica de colocação de uma sutura extra-articular iliofemoral, descrita originalmente por Slocum e Devine (1987), aplicando duas âncoras ósseas e um sistema de fixação, descrevendo as complicações associadas com este procedimento.

A amostra compreendeu sete cães, tendo sido requerido um período mínimo de 4 semanas de acompanhamento. Foram verificadas 29% (2/7) de complicações, incluindo infeção da sutura e reluxação.

Os resultados deste estudo sugerem que a técnica de sutura extra-articular iliofemoral com âncoras ósseas parece ser um método eficaz para o tratamento de luxações coxofemorais craniodorsais, mas mais estudos são necessários para investigar os fatores associados com a seleção do paciente que podem ter justificado algumas das complicações pós-operatórias identificadas.

Palavras-chave: Luxação, anca, craniodorsal, sutura iliofemoral, âncora óssea, sistema de fixação

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LIST OF ABREVIATIONS AND SYMBOLS

> – more than

< – less than

3 – D – Three-dimensional

cm – Centimetre

CT – Computed tomography

FHNEA – Femoral head and neck excision arthroplasty

HVO – Hospital Veterinário do Oeste

IM – Intramuscular

IV – Intravenous

Kg – Kilogram

mg/kg – Milligrams per kilogram

mm – Millimetre

mmHg – Millimetre of mercury

MNL – Monofilament nylon leader

NSAIDs – Nonsteroidal anti-inflammatory drugs

OA – Osteoarthritis

PVI – Povidone-iodine

SC – Subcutaneous

SWI – Surgical wound infection

I – INTERNSHIP REPORT

As part of the Integrated Master's Degree in Veterinary Medicine from the Faculty of Veterinary Medicine - University of Lisbon, I completed a 6-month internship at Hospital Veterinário do Oeste, Lourinhã, Portugal, under the supervision of Dr. Pedro Requicha and co-supervision of Dr. Lisa Mestrinho. This internship was undertaken between 3rd October 2016 and 31st March 2017, with a total of approximately 1950 hours.

During the internship period, I rotated through the services of Internal Medicine, Diagnostic Imaging and Surgery and had the opportunity to assist and participate in several procedures carried out in these areas.

In the Internal Medicine service, I had the opportunity to participate in patient appointments, care and treatment of inpatients (e.g. physical examination and monitoring, wound management, drug administration, blood sampling, catheterization, cystocentesis), I developed clinical case solving skills and learned to perform several diagnostic tests in the Hospital's Laboratory (e.g. complete blood count, electrolytes and chemistry panel; SNAP FIV/FELV SNAP Combo test; SNAP cPLI and fPLI tests; SNAP Parvovirus test; cytology sample collection, preparation, staining and evaluation; urinalysis and urine culture; bacterial culture and antibiotic susceptibility testing).

In the Diagnostic Imaging department, I assisted the veterinarians during radiographic examination, abdominal ultrasound, echocardiography, endoscopy and computed tomography scans.

In the Surgery department, I had the opportunity to participate in the preoperative preparation of the patient, surgical procedures and postoperative patient care. I collaborated in several orthopaedic surgeries (e.g. Tibial Tuberosity Advancement, Fracture repairs, Transcarpal arthrodesis, Elbow arthroscopy, Femoral head and neck excision arthroplasty), soft tissue surgeries (e.g. orchiectomy, ovariohysterectomy, mastectomy, splenectomy, gastrotomy, exploratory laparotomy) and I was also able to develop my surgical skills by performing surgical procedures under the supervision of Dr. Pedro Requicha, such as wound closure, orchiectomy and dentistry procedures. In terms of Anaesthesia I was able to perform patient induction, intubation and general anaesthesia monitoring, under the supervision of an anaesthetist.

I also had the opportunity to attended monthly scientific meetings provided by HVO, which had the aim of deepening the clinicians' knowledge and skills in certain subjects of veterinary clinical practice. During my period of internship, I presented a total of 5 lectures to the HVO team, with an auto proposed or suggested subject approved by my supervisor.

II – INTRODUCTION

Coxofemoral luxations are a common traumatic injury seen in small animal practice, representing up to 90% of all luxations in dogs and cats (Bone, Walker, & Cantwell, 1984; Basher, Walter & Newton, 1986; McLaughlin, 1995). Coxofemoral luxation is a traumatic displacement of the femoral head from the acetabulum generally resulting from external trauma, 59% to 83% caused by motor vehicular accidents, followed by falls, unknown accidents and spontaneous luxation (Holsworth & DeCamp, 2003; DeCamp, 2016). About 35% to 55% of patients have additional traumas to the musculoskeletal, respiratory, urogenital, neurological and gastrointestinal systems (Holsworth & DeCamp, 2003).

There is no breed or gender predisposition, however, studies revealed that German shepherds, mixed breeds and poodles were considerably overrepresented (Bone et al., 1984). Most cases are described in patients over 1 year of age (Denny & Butterworth, 2000), and the average age at the time of diagnosis is 4 to 5 years (Bone et al., 1984; Basher et al., 1986).

Hip luxations are classified into craniodorsal, caudodorsal and ventral, depending on the direction in which the femoral head rests in relation to the acetabulum. Craniodorsal luxations are the most frequent, being observed in 78% of dogs (DeCamp, 2016).

Clinical signs are associated with sudden onset, pain, limb deformity, crepitus and limited or abnormal movement of the affected limb. More specific signs vary depending on the location of the femoral head in relation to the acetabulum (DeCamp, 2016). Diagnosis is relatively simple based on history, clinical findings and radiographic evaluation of the hip (Bone et al., 1984).

Although coxofemoral luxations are not considered an emergency situation, it is advisable to treat them as quickly as possible to avoid additional damage to the soft-tissue surrounding the hip joint and degeneration of articular cartilage (Fossum, 2013). Delay in reduction can increase the extent and severity of cartilage injury and allows progression of inflammation, fibrosis and pelvic muscle contracture. Thus, reduction becomes considerably harder after 4 or 5 days after injury (McLaughlin, 1995; Evers, Johnston, Wallace, Lipowitz, & King, 1997).

Reduction is the treatment of a luxation and the intent is to obtain sufficient joint stabilization, allowing soft-tissue to heal and return to normal function. Reduction and stabilization techniques include closed or open possibilities. The choice is based on the presence of pre-existing disease, type, duration of the luxation, severity of concomitant injuries, patient's weight and activity level, direction of the luxation, extent of injury to the cartilage and joint capsule, economic restrictions and surgeon's preference (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012).

In certain cases, reduction is not recommended due to the duration of the luxation, poor hip conformation or irreparable fractures of the acetabulum or femoral head (DeCamp, 2016). In these cases, there is no reasonable chance of maintaining long-term reduction after a stabilization procedure and a salvage procedure like FHNEA or total hip replacement must be considered (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012).

The present work is divided into two parts:

The first part consists of a literature review which describes the reduction and stabilization techniques used for hip luxation.

The second part consists of a systematic review of 7 clinical cases of craniodorsal hip luxation treated surgically using extra-articular iliofemoral suture placement with bone anchors for stabilization of the coxofemoral joint.

1 – ANATOMY AND BIOMECHANICS OF THE HIP JOINT

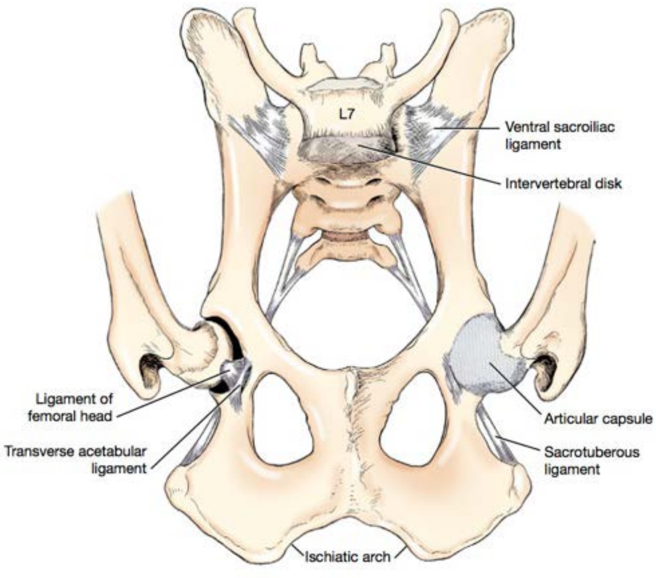
1.1 – Anatomy

The hip joint, or coxofemoral joint (Figure 1), is a diarthrodial articulation between the femoral head and acetabulum, a condyloid cavity bordered by the body of the ilium craniolaterally, the body of the ischium caudolaterally and the body of the pubis medially (Wardlaw & McLaughlin, 2012; Evans & Lahunta, 2013). The acetabulum is deepened by a fibrocartilaginous band, the acetabular lip, which is applied to the dorsal acetabular rim (König & Liebich, 2004).

Diarthrodial joints are complex structures composed of hyaline articular cartilage, synovial lining tissue, joint capsule and ligaments (Bojrab & Monnet, 2010).

The articular surfaces of the bones that compose the coxofemoral joint are covered by hyaline articular cartilage, which is a smooth, resilient and avascular structure that reduces friction and absorbs shocks, cushioning bones from impacting against each other during a weight-bearing activity (Junqueira & Carneiro, 2013). The joint capsule is a closed cavity that surrounds the joint, consisting of an outer fibrous layer and an inner vascularized synovial membrane that is responsible for producing synovial fluid. The synovial fluid is colourless, transparent, viscous and highly rich in hyaluronic acid. It provides lubrication and supplies the joint with nutrients and oxygen, acting as a transport system between the articular cartilage and the blood on the capillaries of the synovial membrane (Junqueira & Carneiro, 2013).

Figure 1 – Ventral view of the ligaments of the canine coxofemoral joint. (Adapted from: Evans & de Lahunta, 2010)



The femur's surface is modelled by the origin and attachment of strong muscles and their tendons, presenting prominent bony protuberances. It is the proximal extremity of the femur that bears the femoral head, a hemispherical articular surface that articulates with the acetabulum, which is interrupted by the *fovea capitis*, the insertion site of the ligament of the femoral head (König & Liebich, 2004). The ligaments are longitudinally orientated bundles of collagen fibres that connect the bones and support the joints, and these can either be incorporated in the joint capsule, as cord-like thickenings, or separated from it by outpouchings of the synovial lining named bursae (Denny & Butterworth, 2000).

The inherent stability of the spheroidal configuration is augmented by the three primary stabilizers of the hip joint: the ligament of the femoral head, which is largely intracapsular and covered by synovial membrane, extending from the acetabular fossa to the *fovea capitis*; the joint capsule, which attaches medially to the acetabular lip and laterally on the femoral neck, and the dorsal acetabular rim (Denny & Butterworth, 2000; Wardlaw & McLaughlin, 2012). Luxation occurs when there is functional loss of two or more primary stabilizers of the hip joint (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012).

Secondary stabilization is provided by the acetabular lip, hydrostatic pressure created by the presence of fluid within the joint and periarticular musculature, which courses over the hip joint in various planes originating from the lumbosacral spine and pelvis to the femur (Fox, 1991; Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012). The periarticular musculature includes the deep, middle and superficial gluteal muscles, which lie dorsal and cranial to the hip joint , that not only have the main action to extend the hip joint but also abduct, internally rotate and prevent lateral rotation during weight bearing (Evans & Lahunta, 2013); iliopsoas muscle; gemelli muscle; quadratus femoris muscle and internal and external obturator muscles (Figure 2 and 3) (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012).

Figure 2 – Lateral view of the areas of muscle attachment on the left hip bone. (Adapted from: Evans & de Lahunta, 2013)

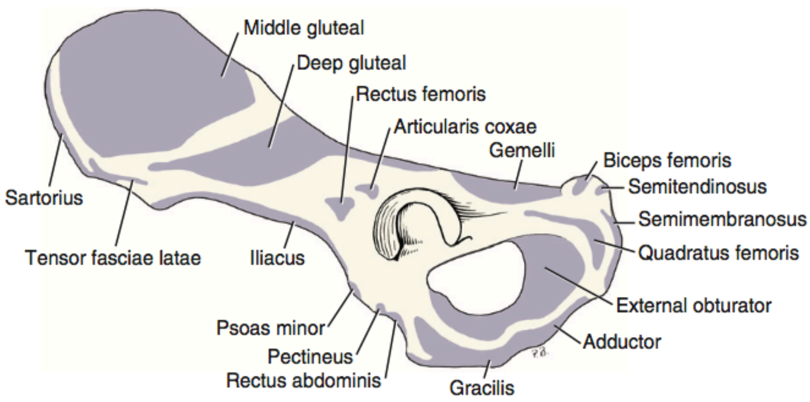
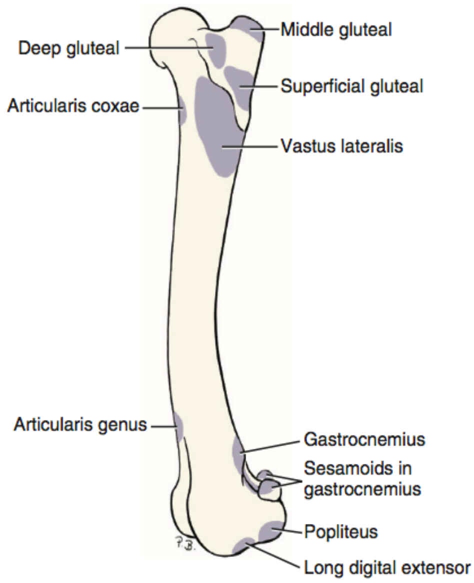


Figure 3 – Lateral view of the areas of muscle attachment on the left femur. (Adapted from: Evans & de Lahunta, 2013)



1.2 – Biomechanics

The coxofemoral joint is a diarthrodial articulation between the femoral head and the acetabulum that allows a wide range of motion in extension, flexion, abduction and adduction due to its ball-and-socket configuration (Denny & Butterworth, 2000; Evans & Lahunta, 2013). There is no well-defined end-point to motion in any direction and it is the tension created by surrounding soft tissue, mainly muscles, that limits the range of motion (Denny & Butterworth, 2000; Bojrab & Monnet, 2010).

The coxofemoral joint is the most susceptible to trauma of all joints because its anatomical structure has no collateral ligaments and the muscles that attach to the proximal end of the femur allow a great range of motion in the joint. The main stabilizing aspect of this joint is the spheroidal configuration itself, the contraction of the adjacent muscles and the anti-cavitational effect of synovial fluid (Bojrab & Monnet, 2010).

The ligament of the femoral head and joint capsule, which provide passive restraint, do not play a major role in preventing luxations of the hip joint as they are easily stretched structures during trauma. The risk is greater in dysplastic patients, where the conformation of the hip is poor and the passive elements of joint stability are already stretched (Bojrab & Monnet, 2010).

2 – COXOFEMORAL LUXATION

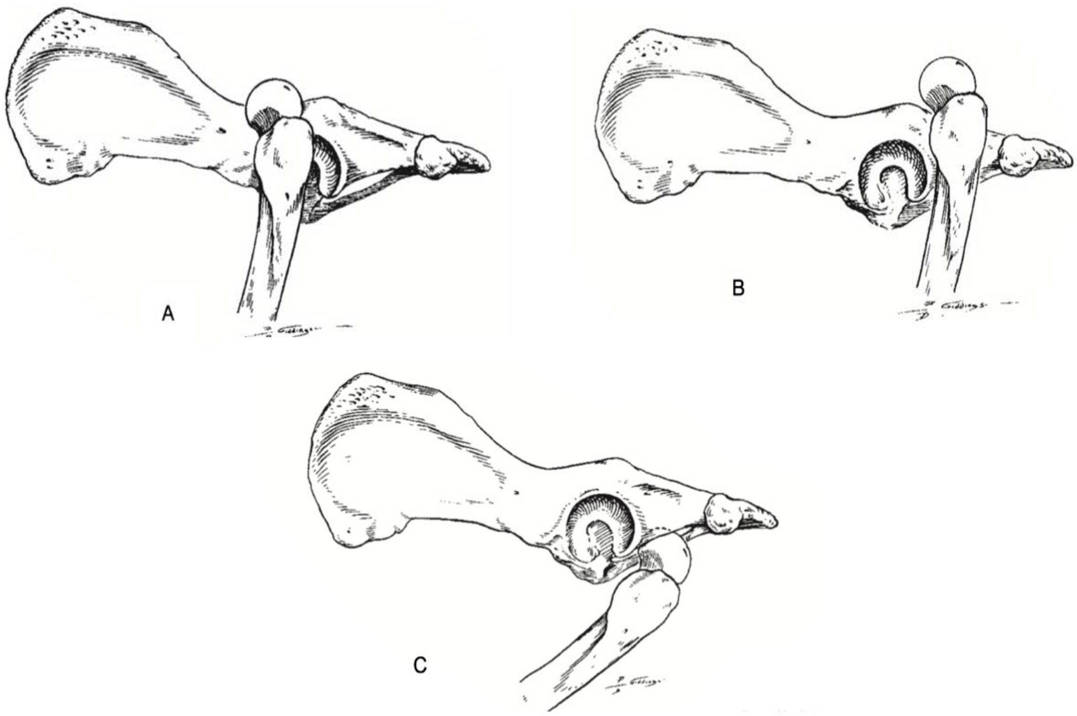
2.1 – Etiology

Coxofemoral luxations in dogs are a consequence of traumatic injuries and the most recent literature classifies luxations into craniodorsal, caudodorsal and ventral, according to the direction in which the femoral head luxates in relation to the acetabulum (Figure 4) (DeCamp, 2016). Studies reveal that unilateral craniodorsal luxations are the most common type of coxofemoral luxation, seen in 78% of affected dogs (Basher et al., 1986; DeCamp, 2016), and bilateral luxations occur only in 3% to 6% of canine hip luxations (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012).

Literature shows that vehicular trauma is the cause of up to 83% of coxofemoral luxations, followed by falls, unknown accidents, spontaneous luxations and severe hip dysplasia (Bone et al., 1984; Basher et al., 1986; Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012; DeCamp, 2016).

Due to the massive forces required to produce luxation, up to 55% of patients with coxofemoral luxation have concurrent injures to other body systems (Bone et al., 1984; Basher et al., 1986; McLaughlin, 1995; Wardlaw & McLaughlin, 2012). Such injuries include chest trauma (e.g. diaphragmatic hernias, pneumothorax, pulmonary contusions), urinary tract injury (e.g. bladder rupture), internal hemorrhage, neurologic injuries and fractures (Basher et al., 1986; McLaughlin, 1995).

Figure 4 – Lateral view of craniodorsal (A), caudodorsal (B) and ventral (C) coxofemoral luxation. (Adapted from: DeCamp, 2016)



2.2 – Biomechanics of luxation

Joint luxation is the result of severe trauma to a joint's supporting structures (McLaughlin, 1995). During trauma, forces directed at the appendicular skeleton are transmitted along the limb, resulting in a joint subluxation or luxation (Bojrab & Monnet, 2010). The resultant sequelae of this trauma depends on several factors such as: direction and speed of force; position of the patient; age of the patient; configuration of the bones and joints and pre-existing joint disease (e.g. hip dysplasia, joint laxity) (Bojrab & Monnet, 2010). For luxation to occur, a portion of the joint capsule must tear as well as the ligament of the femoral head (DeCamp, 2016). The extent of soft-tissue damage varies and additional injuries include damage to the articular surfaces, bone fractures, tendon tear, capsular tissue avulsion, physis separation in young patients and, in more severe cases, one or more gluteal muscles may be partially or completely torn (Bojrab & Monnet, 2010; DeCamp, 2016). Damage to the articular surfaces occurs not only because of the initial trauma but also because the lubrication and nourishment provided by the synovial fluid are also lost (McLaughlin, 1995).

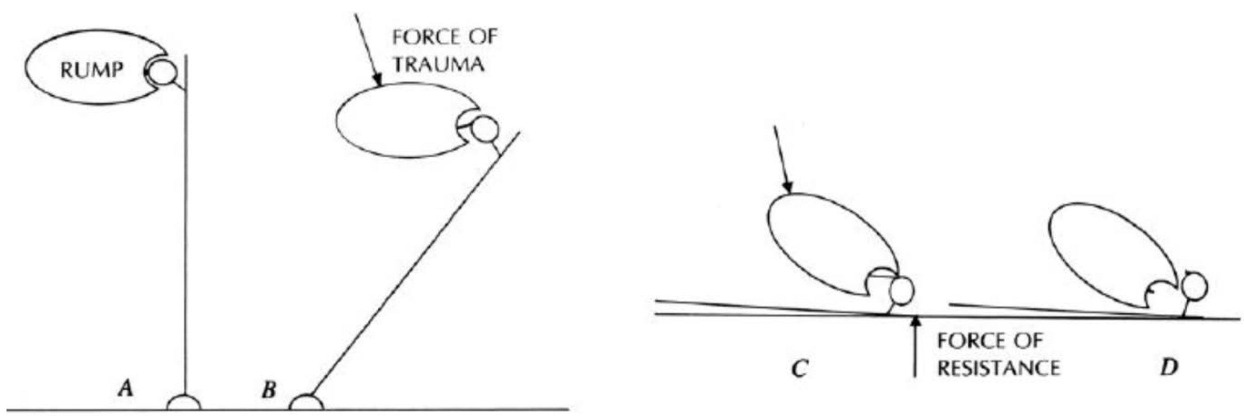
Craniodorsal luxation

Craniodorsal luxations occur when a strong blow is applied behind or to the side of the dog, or when a ventrally directed force is applied to the pelvis (Bojrab & Monnet, 2010; Wardlaw &

McLaughlin, 2012). In the first case, when the animal starts to fall towards the hip to be luxated, the hindlimb moves into adduction and the lever action of the adducted femoral shaft distracts the femoral head from the acetabulum and stretches the joint capsule and ligament of the femoral head. In dysplastic patients, this position is exacerbated due to poor hip joint conformation and because the joint capsule and ligament of the femoral head are already stretched (Figure 5, A and B) (Bojrab & Monnet, 2010). When the great trochanter hits the ground, the energy of the bump is transmitted to the femoral head, which is forced over the dorsal acetabular rim, rupturing the joint capsule and the ligament of the femoral head, allowing the femoral head to luxate into a craniodorsal position (Figure 5, C and D) (Bojrab & Monnet, 2010; Wardlaw & McLaughlin, 2012). Sometimes, avulsion of this ligament occurs and a small fragment of the femoral head is pulled (Bojrab & Monnet, 2010). Very rarely, a fragment of bone is chipped off from the dorsal rim of the acetabulum (Bojrab & Monnet, 2010). One of the reasons as to why the femoral head most commonly luxates into a craniodorsal position is the force that the gluteus muscles exert in this direction, mainly the middle gluteal muscle (Bojrab & Monnet, 2010; Wardlaw & McLaughlin, 2012).

In the second case, luxation may occur if the limb is in adduction and a ventrally directed force is applied to the pelvis. If the force is sufficient, rupture of the joint capsule and ligament of the femoral head occurs, allowing the femoral head to luxate (Bojrab & Monnet, 2010). Similarly to the first case, the pull of the gluteus muscles aids in displacing the femoral head craniodorsally (Bojrab & Monnet, 2010; Wardlaw & McLaughlin, 2012).

Figure 5 – Illustration of the mechanism of luxation into a craniodorsal direction. (A) Hindlimb viewed from the front. (B) A blow is struck to the rump causing the limb to go into adduction. (C) The femoral head is forced over the dorsal acetabular rim. (D) Rupture of the joint capsule and ligament of femoral head, allowing luxation into a craniodorsal position. (Adapted from: Bojrab, & Monnet, 2010)



Caudodorsal luxation

This is a rare condition and may simply be a craniodorsal luxation with a greater degree of instability, which allows the femoral head to move caudally (DeCamp, 2016).

Ventral luxation

Studies indicate that ventral luxations represent about 1.5% to 3.2% of hip dislocations and may or may not occur associated with acetabular impact fractures (Harari, Smith & Rauch,1984; Thacker & Schrader,1985; DeCamp, 2016). In nonfracture cases, the femoral head lies ventral to the acetabulum, usually in the obturador foramen, or hooked under the iliopectinial eminence (DeCamp, 2016).

Ventral luxations can be cranioventral or caudoventral. Cranioventral may occur iatrogenically, when attempts are made to reduce craniodorsal luxations, and caudoventral can occur spontaneously from trauma and may be accompanied by fractures of the greater trochanter (Wardlaw & McLaughlin, 2012; DeCamp, 2016).

2.3 – Clinical presentation - History and signs

Owners usually provide a history of observed or suspected physical trauma (McLaughlin, 1995), which is defined as a suddenly applied force that results in anatomical and physiological alterations (Morgan & Wolvekamp, 2004). Consequences of trauma can be focal or generalized, and the injury to the musculoskeletal system varies, resulting from a patient with apparently minimal injury, characterized by a weight-bearing or non-weight-bearing lameness, to a patient who is paralyzed, or even in severe shock (Morgan & Wolvekamp, 2004). Stabilization of the hemodynamically unstable patient takes priority over any orthopaedic injury, being of maximum importance the initiation of emergency procedures. Once the patient is stable, orthopaedic and neurological examinations can be performed (Lafuente, 2013).

Some injuries are readily observed, while others are not so evident, therefore, to minimize the chances of overlooking potentially life threatening conditions, it is essential to approach the trauma patient in a methodical way (Lafuente, 2013). Patients may be presented for observation immediately after trauma or presentation may be delayed, due to the inability of the owners to recognize the injury or absence of the animal from home (Morgan & Wolvekamp, 2004).

The majority of patients with coxofemoral luxation have a history of obvious trauma witnessed by the owner, whereas other patients are presented with a history of having been found recumbent or having returned home unable to walk normally (Morgan & Wolvekamp, 2004). Further investigation will lead to a history of sudden onset non-weight-bearing lameness, pain, deformity, crepitation and abnormal or limited movement of the affected limb (DeCamp, 2016).

If bilateral coxofemoral luxation is present, or unilateral coxofemoral luxation is combined with a concomitant orthopaedic injury, the patient is typically unable to walk (Wardlaw & McLaughlin, 2012).

2.4 – Orthopaedic examination

Following a thorough general clinical examination, orthopaedic assessment generally begins with observation of the patient's gait and posture followed by a systematic physical examination of all the patient's limbs (Witte & Scott, 2011). Physical examination begins with the patient standing, with the affected hindlimb being the last to be examined, thus minimizing the chances of overlooking findings on other limbs (Arthurs, 2011). Examination of the affected hindlimb should be performed simultaneously with the contralateral limb, and consists of palpation and manipulation of musculature, bones and joints (Witte & Scott, 2011).

Possible findings during examination are abnormalities in limb weight-bearing, asymmetry between hindlimbs, response to pain, soft tissue swelling, abnormalities in range of motion, instability, crepitation, poor bone alignment, asymmetric joints and unilateral or bilateral quadriceps, hamstrings and gluteal muscles atrophy in chronic cases (Arthurs, 2011; DeCamp, 2016). A basic neurological examination on all limbs should also be performed and includes assessing conscious proprioception (e.g. knuckling and paper-slide tests) and response to spinal reflexes (Witte & Scott, 2011).

Joint manipulation is probably the most uncomfortable part of the physical examination and should, for this reason, be performed slowly, gently and preferably last (Witte & Scott, 2011). Hip joint manipulation should isolate flexion–extension from adduction–abduction and should also assess internal and external rotation (Witte & Scott, 2011). A normal hip has a wide range of pain and crepitus free movement and the hip should flex to about 50° and extend to about 160° (Arthurs, 2011). Sedation or general anaesthesia is advisable to perform these manoeuvers adequately as pain and muscle spasm will diminish their diagnostic value in the conscious patient (Witte & Scott, 2011).

It is impossible to fully extend the hip without simultaneously extending the stifle and increase patellofemoral contact pressure; therefore, if concurrent stifle disease is present, this may cause stifle pain, giving a false positive pain response to hip extension. Hence, a positive pain response to hip extension must be interpreted carefully and stifle disease ruled out previously to avoid a false positive result (Arthurs, 2011). Furthermore, physical examination should also differentiate between lumbosacral pain and hindlimb pain, even in the absence of hindlimb proprioceptive deficits (Witte & Scott, 2011). A false positive pain response to hip extension can occur if lumbosacral disease is present because hip extension inevitably results in lumbosacral extension, exerting pressure onto the lumbosacral spine. Conversely, hindlimb abduction will generally not be resented in a dog with lumbosacral disease, unless there is concurrent hip osteoarthritis (Arthurs, 2011; Witte & Scott, 2011).

Anatomic landmarks to palpate in the pelvis include the tuber ischii, the greater trochanter and the iliac crest; however, palpation may be difficult in obese patients (DeCamp, 2016). Each of these structures should be palpated to check for discomfort, swelling and changes in texture, shape or position (Arthurs, 2011). The relative positions of these three landmarks make the shape of a triangle in the normal patient (Figure 6). This relationship is lost in pelvic fractures, hip luxations, femoral head fractures and chronic coxofemoral arthritis (Arthurs, 2011; DeCamp, 2016).

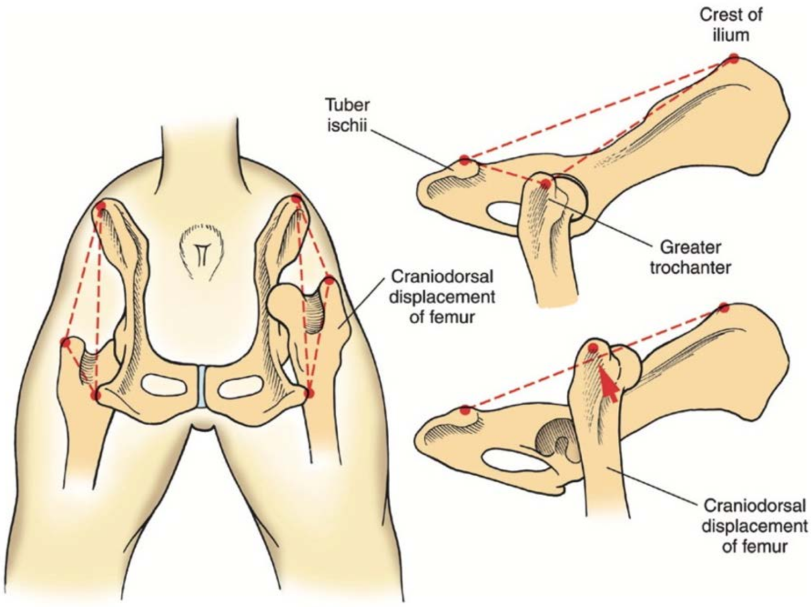
Once the standing examination is concluded, the patient is placed in lateral recumbency to examine the previously noted abnormalities (DeCamp, 2016). To detect pain, crepitation and instability, the femur is grabbed by the stifle joint and the hip is flexed and extended several times. If pain or crepitus are not produced, external hip rotation is added to the previously mentioned maneuvers (DeCamp, 2016). In a normal joint, placing the thumb in the ischiatic notch (the space between the greater trochanter and the tuber ischii) and externally rotate the femur, will displace the thumb from the ischiatic notch. However, if the coxofemoral joint is luxated, the thumb will not be displaced when the femur is externally rotated (Wardlaw & McLaughlin, 2012; Fossum, 2013).

For patients that resent hip extension, abduction and internal rotation, a differential diagnosis should include iliopsoas strain. Specific palpation of the iliopsoas muscle belly, iliopsoas tendon and insertion site of the tendon on the lesser trochanter will cause significant discomfort in cases of iliopsoas strain (Witte & Scott, 2011).

Craniodorsal Luxation

The femoral head rests dorsal and cranial to the acetabulum (DeCamp, 2016). Clinical findings include pain in the hip region, crepitus of the hip joint, non-weight-bearing lameness, external rotation and adduction of the affected limb. Craniodorsal luxations make the affected limb appear shorter than the contralateral limb when positioned ventrally and extended caudally (Wardlaw & McLaughlin, 2012; DeCamp, 2016). On palpation, there is marked asymmetry of the hips due to dorsal displacement of the greater trochanter in the affected limb and increased distance between the greater trochanter and the tuber ischii (Figure 6) (DeCamp, 2016).

Figure 6 – Illustration of a craniodorsal displacement of the femur. The greater trochanter is dorsal to an imaginary line drawn from the iliac crest to the tuber ischii. (Adapted from: Fossum, 2013)



Caudodorsal Luxation

The femoral head rests dorsal and caudal to the acetabulum, with some risk of sciatic nerve injury (DeCamp, 2016). Clinical findings common with this type of luxation include pain in the hip region, non-weight-bearing lameness, internal rotation and abduction of the affected limb (Fossum, 2013).

When the limb is extended caudally, there is apparent increase in limb length, however, when the limb is positioned ventrally, it seems that limb length decreases. On palpation, there is a narrowing of the space between the greater trochanter and the tuber ischii (DeCamp, 2016).

Ventral Luxation

The femoral head rests ventral to the acetabulum usually in the obturator foramen, or cranial to the acetabulum, hooked under of the iliopectineal eminence (DeCamp, 2016). Clinical findings common with this type of luxation include pain in the hip region, non-weight–bearing lameness, internal rotation, abduction and apparent lengthening of the affected limb (Wardlaw & McLaughlin, 2012). Palpation of the greater trochanter is difficult, as it is ventrally displaced (DeCamp, 2016).

Ventral luxations cause the greatest degree of disability and pain, which may be due to pressure on the obturator nerve. This pressure occurs as a result of the femoral head resting in the obturator foramen the majority of times, as previously mentioned (Denny & Butterworth, 2000).

2.5 – Diagnostic Imaging

Although from history, physical examination and clinical pathognomonic signs of coxofemoral luxation is possible to determine the presence of luxation, complementary imaging tests to confirm the diagnosis are necessary to determine the direction of luxation, exclude the existence of concomitant lesions and decide the most appropriate treatment technique (Denny & Butterworth, 2000; Holsworth & DeCamp, 2003). Possible concomitant lesions to be found are avulsion fractures at the insertion site of the ligament of the femoral head in 5% to 10% of cases, acetabular fractures in 4% of cases, greater trochanter fractures in 1% of cases, femoral head or neck fractures, pelvis fractures, luxation of the sacroiliac joint and slipped capital epiphysis in immature dogs (Basher et al., 1986; McLaughlin, 1995; Denny & Butterworth, 2000; Holsworth & DeCamp, 2003; DeCamp, 2016). The slippage of the capital epiphysis in immature patients results in a loss of blood supply to the femoral head, due to the intracapsular location of the physis, leading to a subsequent necrosis of the femoral head unless reduction and stabilization are immediate and anatomically successful (Morgan & Wolvekamp, 2004).

Furthermore, the presence of hip dysplasia, Legg-Calvé-Perthes disease and bone fragments in the joint space have a great influence on the choice of treatment since they prevent good stabilization after reduction (Denny & Butterworth, 2000; DeCamp, 2016).

2.5.1 – Radiography

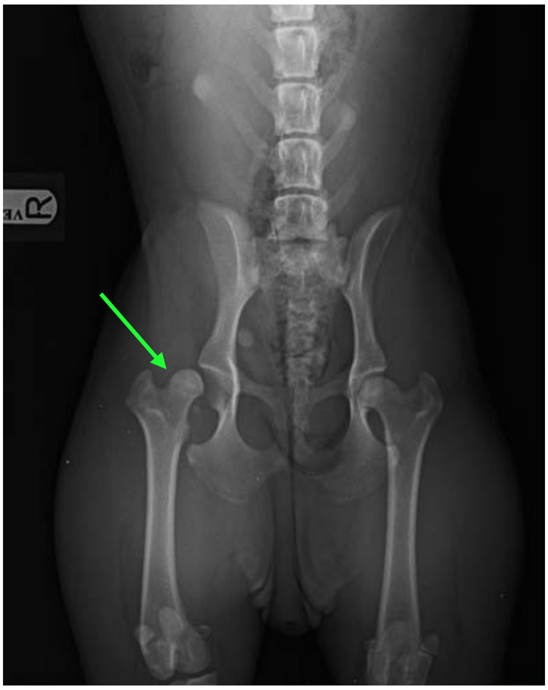
The acquisition of radiographs is one of the most common examinations performed in veterinary practice and it is considered the mainstay for assessing the skeleton. However, there is a superimposition of structures and they provide minimal information on other joint structures (Thrall, 2013).

In general, two standard orthogonal projections of the pelvis, ventro-dorsal and lateral, are obtained before attempting reduction (Figure 7) (McLaughlin, 1995). Ventro-dorsal views of the pelvis are commonly used to determine the degree of laxity in the coxofemoral joints and to examine the joints for signs of osteoarthritis (Witte & Scott, 2011).

Lateral views of the pelvis are used to determine the position of a luxated coxofemoral joint and for evaluating pelvic symmetry.

When radiographs are taken without sedation or anaesthesia, correct positioning of the patient is not achieved, thus, the quality of radiographs and diagnosis are often compromised (Leppänen et al., 2006). Therefore, to obtain a good-quality diagnostic view of the ventro-dorsal hip-extended pelvis, it is advisable to sedate the patient to obtain good muscle relaxation and extend the limb fully. (Brown & Brown, 2014).

Figure 7 – Ventrodorsal radiograph of the pelvis of a dog with right craniodorsal coxofemoral luxation. (Dispensed by HVO)



2.5.2 – Computed Tomography

CT enables more detailed and specific morphological diagnosis than radiography, being excellent for evaluating bony structures and soft tissue (Figure 8). While radiographs represent two-dimensional projections of three-dimensional structures, with CT tissues are examined in thin sections, eliminating superimposing (Thrall, 2013) .

Intrapelvic soft tissue injuries are much more accurately assessed on CT, including muscle tears, muscle attachment avulsion and femoral nerve injuries (Schwarz & Saunders, 2011). If pelvic fracture with displacement is identified, a secondary fracture or a sacroiliac luxation must also be present (Schwarz & Saunders, 2011).

Furthermore, CT volume datasets can be reformatted in any imaging plane, or as 3-D projections, allowing better representations of structural anatomic relationships. Three-dimensional projections are also useful in surgical planning (Figure 9) (Schwarz & Saunders, 2011; Thrall, 2013).

Figure 8 – CT scan of a dog with coxofemoral luxation. (Dispensed by HVO)

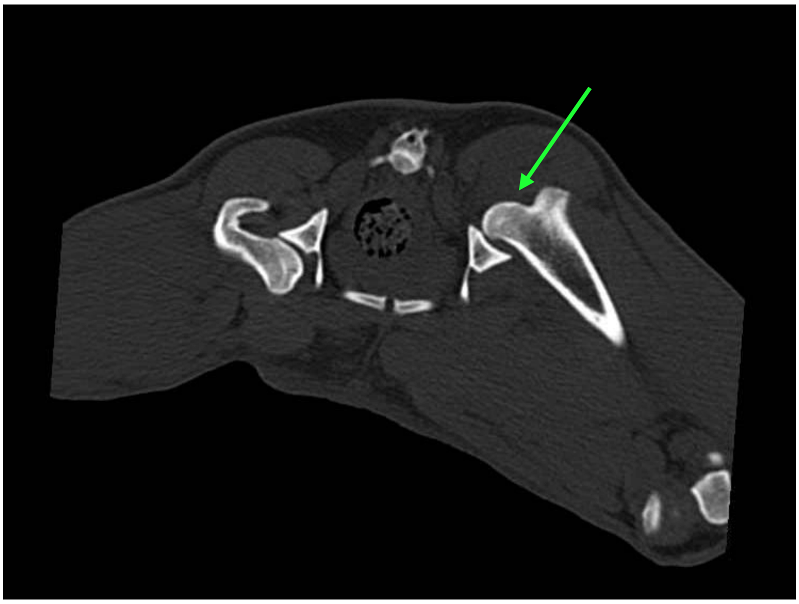
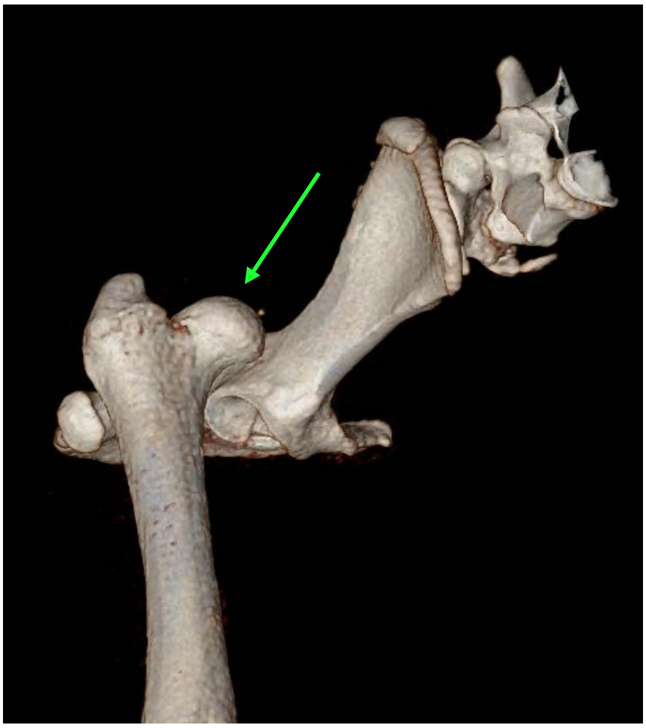


Figure 9 – Three-dimensional projection of a dog with coxofemoral luxation. (Dispensed by HVO)



3 – TREATMENT OPTIONS OF COXOFEMORAL LUXATION

The coxofemoral joint should be reduced as soon as possible to minimize destruction of articular cartilage, progression of inflammation, and before pelvic muscle contraction and fibrosis difficult easy relocation (Wardlaw & McLaughlin, 2012). Although hip luxation is not considered a surgical emergency, it should be treated within 72 hours to diminish pathologic changes to the femoral head and acetabulum (Wardlaw & McLaughlin, 2012).

After several days, muscle contracture and degeneration of the joint capsule occurs, preventing adequate reduction of the femoral head. Within 7 to 10 days after trauma, the crushing movement of the luxated femoral head leads to a maceration of the capsule and acetabular joint capsule coverage reduction over the femoral head (DeCamp, 2016). Within 14 to 21 days, fibrous scar tissue begins to immobilize the displacement to the gluteal muscles or shaft of the ilium, anchoring the femoral head (DeCamp, 2016).

Reduction and stabilization of the coxofemoral joint is accomplished by using closed or open techniques and the choice of treatment is based on the presence of pre-existing disease (e.g. hip dysplasia), type and duration of luxation and severity of concomitant injuries (Wardlaw & McLaughlin, 2012; Fossum, 2013).

Studies show that it is reasonable to attempt closed reduction first to avoid surgery (Bone et al., 1984). Open reduction is indicated as first choice when there are concomitant fractures of the acetabulum or femoral head, with avulsion fractures of the femoral head, when immediate mobility of the patient is needed to treat concomitant injuries or the luxation is chronic and visualization of the cartilage is necessary (Wardlaw & McLaughlin, 2012; Fossum, 2013; DeCamp, 2016). In cases where reduction cannot be maintained, due to poor hip conformation or irreparable fractures of the acetabulum or femoral head, FHNEA or total hip arthroplasty is the recommended procedure (Bone et al., 1984; Wardlaw & McLaughlin, 2012).

3.1 – Closed Reduction

Although open reduction seems to be more effective in the treatment of coxofemoral luxations, some patients can be treated with closed reduction when there are no complicating factors such as muscle contracture, intra-articular fractures, presence of soft tissue (e.g. joint capsule, hematoma, inflammation of the ligament of the head of the femur and fat pad) within the acetabulum or periarticular fibrosis (Wardlaw & McLaughlin, 2012; DeCamp, 2016) .

Patients with hip dysplasia, severe OA, avulsion of the ligament of the head of the femur, concurrent ipsilateral fractures of the hemipelvis and with chronic luxations are poor candidates for closed reduction (Denny & Butterworth, 2000; Bojrab & Monnet, 2010; Wardlaw &

McLaughlin, 2012). Furthermore, avulsion of the ligament of the head of the femur is a contraindication to closed reduction since it will leave a bone fragment in the joint space, which can lead to reluxation or rapid onset of OA due to the damage to the articular surfaces (Denny & Butterworth, 2000; DeCamp, 2016;).

Craniodorsal Luxation

In craniodorsal luxations the joint capsule can theoretically rupture in three places: midway between the acetabulum and neck of the femur, avulsion from the acetabulum and avulsion from the neck of the femur (DeCamp, 2016). The first type is the most common and the one that responds better to closed reduction. The second type results in a very unstable hip, since the acetabular lip is missing, and the third type prevents deep-seated reduction since the joint capsule lies across the acetabulum like a "hammock" (DeCamp, 2016).

As mentioned, closed reduction technique begins with anaesthesia and placing the dog in lateral recumbency. A soft cotton rope or small towel is placed in the inguinal area, where it can be held by an assistant or secured in the edge of a surgical table, to provide countertraction and stabilize the pelvis during reduction (Denny & Butterworth, 2000; Wardlaw & McLaughlin, 2012; DeCamp, 2016). First, the femoral head is disengaged from the dorsal acetabular rim by grasping the hock and stifle and externally rotate the limb. This is followed by traction in a distocaudal direction and internal rotation to align the femoral head over the acetabulum. Then, the limb is abducted and downward pressure is applied directly to the greater trochanter to guide the femoral head towards the acetabulum, achieving reduction (Wardlaw & McLaughlin, 2012; DeCamp, 2016). Usually, the femoral head can be felt to "pop" into the acetabulum (DeCamp, 2016).

Once the joint is reduced, moderate pressure is applied in the greater trochanter while the joint is manipulated through full range of motion to seat the femoral head as deeply as possible in the acetabulum and displace blood clots, folded joint capsule or granulation tissue (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012; DeCamp, 2016). Radiographic confirmation, as well as assessment of limb length and greater trochanter position are important to determine if reduction was successful (Holsworth & DeCamp, 2003).

If after closed reduction the joint remains unstable and reluxates easily, open reduction or a salvage procedure is necessary (Denny & Butterworth, 2000; Holsworth & DeCamp, 2003).

A similar technique to the one just described is used to reduce caudodorsal luxations (DeCamp, 2016).

Ventral Luxation

Closed reduction of ventral luxations varies whether the luxation is cranioventral or caudoventral. In cranioventral luxations, the femoral head can either be converted to the craniodorsal position and then reduced as described above, or manipulated directly into the acetabulum (DeCamp, 2016).

In caudoventral luxations, the femoral head is disengaged from the obturador foramen using traction and countertraction on the ischiatic tuberosity, while abducting the limb (Wardlaw & McLaughlin, 2012). Once the femoral head is disengaged from the obturador foramen, a levering action is applied to the proximal femur, with the purpose of lifting the femoral head laterally and cranially into the acetabulum (Wardlaw & McLaughlin, 2012; DeCamp, 2016)

3.2 – Stabilization techniques of Closed Reduction

3.2.1 – Ehmer Sling

The Ehmer sling or figure-of-eight bandage is a non-weight-bearing sling applied to the hindlimb, designed to maintain the head of the femur in the acetabulum after closed reduction of a craniodorsal luxation (Roush & Renberg, 2015). The sling maintains the hip joint in flexion with the limb slightly abducted and internally rotated (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012). A radiograph is mandatory after sling application to determine that reduction has been maintained (Holsworth & DeCamp, 2003).

The sling is maintained for a minimum of 7 to maximum 14 days, until the joint capsule and periarticular soft tissues are sufficiently healed to maintain reduction (Roush & Renberg, 2015; DeCamp, 2016). However, if the joint remains unstable, it is unlikely that an Ehmer sling will be sufficient to prevent reluxation (Denny & Butterworth, 2000).

Best results are obtained in acute luxations (less than 24 hours), in lean and calm patients with temperaments amenable to confinement and continual bandage care (Roush & Renberg, 2015). Ehmer slings should not be used in patients with luxations of more than one week duration, associated with fractures of the acetabulum, poor hip conformation (e.g. hip dysplasia) and patients unable to ambulate on the contralateral limb (Roush & Renberg, 2015). An Ehmer sling is also contraindicated in patients with ventral luxation because in this type of luxation limb abduction must be prevented (Roush & Renberg, 2015; DeCamp, 2016) .

It can be difficult to apply in obese and chondrodystrophic patients (Roush & Renberg, 2015), complications include sling loosening, moist dermatitis, decubital ulcer formation, pressure necrosis over the metatarsal or quadriceps regions, oedema and ischemic necrosis of the distal extremity (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012).

Reluxation rates of 15% to 71% have been reported with the use of Ehmer sling alone following closed reduction and the rates are higher if the sling is applied more than five days after luxation (Wardlaw & McLaughlin, 2012).

3.2.2 – Hobbles

To maintain joint reduction after closed reduction of ventral luxations, the hindlimb is maintained in adduction for 2 to 3 weeks by placing hobbles at the level of the stifle to prevent abduction (Wardlaw & McLaughlin, 2012; DeCamp, 2016). However, studies suggest that many ventral luxations are managed successfully without hobbles (Wardlaw & McLaughlin, 2012).

3.2.3 – Ischioilial Pinning

Also known as DeVita pin, it is used to stabilize the hip joint after closed reduction (Wardlaw & McLaughlin, 2012). A Steinmann pin is placed through a stab incision ventral to de ischium, passed cranially over the femoral head, and embedded into the wing of the ilium. The pin is left *in situ* for 2 to 4 weeks, with exercise restriction for an additional 2 to 4 weeks following pin removal (Wardlaw & McLaughlin, 2012).

Studies report that reduction was maintained in up to 73% of dogs however, the complication rate was 32% and included pin migration in 10% to 27% of cases, reluxation, damage to the sciatic nerve, damage to the femoral head, joint sepsis and decubital ulceration (Denny & Butterworth, 2000; Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012).

3.2.4 – External Fixators

External fixation, both rigid and flexible, is another method described to aid stabilization of the hip joint after closed reduction (Wardlaw & McLaughlin, 2012). Fixation pins are inserted through incisions on the skin into the proximal femur and ilium, and connected externally with bars or flexible bands (Wardlaw & McLaughlin, 2012). Accurate pin placement is essential to avoid sciatic nerve injury and for proper biomechanical function (McLaughlin, 1995). The fixator remains in place 2 to 4 weeks, with exercise restriction for an additional 2 to 4 weeks after removal of the fixator (Wardlaw & McLaughlin, 2012). Complications with the use of external fixators include drainage from the pin tracts, disruption of the bands and joint reluxation (McLaughlin, 1995).

3.2.5 – Transarticular Pinning

This procedure can be performed as an open or closed technique and consists in inserting a Steinmann pin or Kirschner wire through the femoral head and neck into the acetabulum to provide joint stability (Wardlaw & McLaughlin, 2012).

For closed insertion, after reduction of the hip, the pin is inserted in a normograde fashion, starting at the level of the third trochanter, aimed towards the *fovea capitis* and inserted through the femoral head and neck into the medial wall of the acetabulum (McLaughlin, 1995; Wardlaw & McLaughlin, 2012). For open insertion, the pin is inserted in a retrograde fashion starting at the *fovea capitis* and exiting near the greater trochanter (McLaughlin, 1995; Wardlaw & McLaughlin, 2012). Then, the joint is reduced and the limb placed in a weight-bearing position, slightly abducted, while the pin is driven through the acetabular wall (Wardlaw & McLaughlin, 2012). In both closed and open insertion techniques, an assistant should evaluate pin depth into the pelvic canal by rectal examination, which must be approximately 5mm (McLaughlin, 1995; Wardlaw & McLaughlin, 2012).

The lateral portion of the pin is bent over and cut to prevent migration in a medial direction and reduce tissue trauma (McLaughlin, 1995; Wardlaw & McLaughlin, 2012).

Complications of transarticular pinning include pin migration, cartilage damage, sciatic nerve injury, perforation of the rectum, pin bending or breakage, osteonecrosis, OA and intra-articular fractures (McLaughlin, 1995; Kiliç, Ozaydin, Atalan, & Baran, 2002; Wardlaw & McLaughlin, 2012).

Transarticular pinning is not recommended due to its high complication rate, and techniques that do not cause additional damage to the articular cartilage are usually preferred (McLaughlin, 1995; Wardlaw & McLaughlin, 2012). However, studies report satisfactory results in 74% to 80% of cases, with worse results in heavier patients (more than 35 kilograms) and those with hip dysplasia (Hunt, 1985; McLaughlin, 1995; Wardlaw & McLaughlin, 2012). In a retrospective study of 40 cases, the most frequent complication was pin breakage, but this did not affect final outcome and could be avoided by using pins of larger diameter (Hunt, 1985).

3.3 – Open reduction

Situations in which the hip remains unstable following closed reduction, or the femoral head cannot be reduced, require an open approach (DeCamp, 2016). Moreover, it allows exploration of the joint, removal of hematoma and soft tissues entrapped within the acetabulum and application of internal stabilization techniques (Wardlaw & McLaughlin, 2012).

With hip luxation, the anatomy of the hip joint is altered and difficult to identify since the muscles surrounding the joint are often bruised and swollen. Therefore, before starting the surgical approach, it is advisable to reduce the hip joint as it makes it possible to establish relatively normal tissue relationships and facilitate surgical dissection (Fossum, 2013; DeCamp, 2016).

The choice of surgical approach varies with the situation, being the two most frequently used the craniolateral and dorsal approaches (Holsworth & DeCamp, 2003). The craniolateral approach of the hip joint is usually sufficient if the hip is reductible; however, if the hip cannot be reduced or the joint capsule cannot be adequately sutured, additional craniolateral exposure can be improved by partial tenotomy of the deep gluteal tendon (DeCamp, 2016). When greater exposure is necessary (e.g. chronic luxation with more than 5 to 6 days or extensive reconstruction is required), dorsal approach with osteotomy of the greater trochanter or tenotomy of the deep and middle gluteal tendons may be performed (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012). Furthermore, a dorsal approach to the hip joint is also recommended in ventral luxations, to obtain adequate exposure (Wardlaw & McLaughlin, 2012).

After exposure of the joint, the extent of damage to the joint capsule should be evaluated to determine whether it can be sutured to help stabilize the joint (Wardlaw & McLaughlin, 2012). Then, the femoral head must be reluxated to assess damage to the joint capsule, femoral head and acetabular rim (Wardlaw & McLaughlin, 2012; DeCamp, 2016). If articular cartilage damage is severe, the prognosis is guarded and total hip replacement or FHNEA should be considered. However, if the articular surfaces have minor damage, soft tissue and clots are removed from the acetabulum, and remnants of the ligament of the femoral head, fat pads and muscle fragments are excised (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012). Exposure of the acetabulum is facilitated by using Hohmann retractors within or caudal to the acetabulum and levering the proximal femur caudally (Fossum, 2013; DeCamp, 2016). After inspection and clearing of the joint, the femoral head is carefully reduced again, in order not to damage the remaining joint capsule and articular surfaces (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012).

Open reduction techniques include capsulorrhaphy, prosthetic capsule technique, transposition of the greater trochanter, toggle rod stabilization, transposition of the sacrotuberous ligament, extra-articular iliofemoral suture placement, fascia lata loop stabilization, FHNEA and total hip arthroplasty (Wardlaw & McLaughlin, 2012). The technique chosen must provide stability for a minimum of two weeks, which is the time that the joint takes to restore its original stability (McLaughlin & Tillson, 1994; Martini et al., 2001). This also depends on various factors including the patient’s weight, activity level, direction of the luxation, extend of injury to the cartilage and joint capsule, concurrent injuries, economic restrictions and surgeon’s preference

(Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012). Studies suggest that all methods have roughly the same rate of good to excellent results; therefore, the choice is a matter of surgeon's preference and availability of equipment (Fossum, 2013; DeCamp, 2016).

3.3.1 – Capsulorrhaphy

Capsulorrhaphy as the sole reconstructive procedure of stabilization of the hip joint requires that the dorsal joint capsule is identifiable and the conformation of the joint is normal (Fossum, 2013). Usually, capsulorrhaphy is used in cases that the joint capsule is intact except for a small rent and there is adequate acetabular coverage to permit proper closure of the joint capsule (Fossum, 2013; Wardlaw & McLaughlin, 2012).

This surgical technique provides stabilization of the hip joint by suturing the torn joint capsule with large, monofilamentous, nonabsorbable or absorbable sutures, which are preplaced in the capsule using a horizontal mattress or cruciate pattern, and then tied with the hip internally rotated and abducted. Preplacement of the sutures allows precise suture placement before tightening (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012; Fossum, 2013). After the capsule has been sutured, stability of the joint is assessed by manipulating the hip through flexion, extension and gentle external rotation (Holsworth & DeCamp, 2003).

An Ehmer sling may be placed postoperatively to reduce limb use and maintain the joint in a stable position (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012). Studies report success rates of 83% to 90%; however, in many cases, the joint capsule is too damaged to permit adequate closure and alternative methods are required to provide joint stability (Wardlaw & McLaughlin, 2012).

3.3.2 – Prosthetic capsule technique

The prosthetic capsule technique is simple and effective (DeCamp, 2016). After reduction, if the joint capsule is damaged or avulsed from the acetabulum, two bone screws of suitable diameter are inserted into the dorsal acetabular rim, at 10 and 1 o'clock for the left hip and 11 and 2 o'clock for the right hip, to serve as anchor points for suture attachment (Wardlaw & McLaughlin, 2012; DeCamp, 2016). The screws are inserted 0,5 to 1 centimetres from the acetabular rim and directed medially to avoid entering the joint and damage the articular surfaces. The size of screws varies with the size of the patient from 2,7 mm, in medium-sized and toy-breed dogs, to 3,5 or 4 mm, in large or giant breed dogs (Wardlaw & McLaughlin, 2012). Stainless steel or plastic washers (flat or spiked) are placed with each screw to prevent suture material slippage from the screw head (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012; DeCamp, 2016). Then, a transversely oriented hole is drilled through the proximal portion of the base of the femoral neck and large monofilament or multifilament suture material is placed in a figure of eight pattern between the acetabular screw heads and the femoral neck hole to prevent reluxation (Wardlaw & McLaughlin, 2012; DeCamp, 2016). The femoral head is reduced, remaining capsular tissue is sutured and the sutures are tied tightly while the limb is positioned in a weight-bearing position with slight abduction and internal rotation (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012). An alternative to screws and washers are bone anchors, which allow attaching the suture directly to bone without having a large screw head present (Wardlaw & McLaughlin, 2012; DeCamp, 2016).

Complications include damage to the articular cartilage by the suture, displacement of the suture from the screw heads, reluxation and infection (Wardlaw & McLaughlin, 2012). Acute lameness 4 to 10 weeks after surgery may be observed and it is related with breaking of the suture material (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012).

The prosthetic capsule technique is reported to prevent reluxation in 66% to 100% of cases with excellent to good outcomes in 65% to 67% of patients, 18% mild lameness and 18% severe lameness (Johnson & Braden, 1987; Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012).

3.3.3 – Transposition of the greater trochanter

In cases that the gluteal musculature is not compromised, transposition of the greater trochanter may be performed (Fossum, 2013). The greater trochanter is transposed distally and slightly caudally to its original location, approximately 1 to 2 cm depending on the patient’s size, providing additional joint stability by increasing the medial pull of the gluteal muscles, abducting and internally rotating the femur (McLaughlin, 1995; Wardlaw & McLaughlin, 2012; Fossum, 2013). The greater trochanter is reattached with a tension band wire fixation or a lag screw (Wardlaw & McLaughlin, 2012). Rarely, the tension band wire causes complications and must be removed (McLaughlin, 1995).

Studies report that this technique alone prevents reluxation in 84% of patients but generally it is used in conjunction with other internal methods of stabilization (McLaughlin, 1995; Wardlaw & McLaughlin, 2012).

3.3.4 – Toggle Rod stabilization

An advantage of this technique is that it allows early use of the limb after surgery, which is particularly important if concomitant injuries to the contralateral hindlimb are present (McLaughlin, 1995).

A hole is drilled through the femoral head and neck from the region of the third trochanter to the *fovea capitis* and a second hole is drilled in the center of the acetabular fossa, penetrating the medial acetabular wall, large enough to accommodate the toggle rod (Wardlaw & McLaughlin, 2012). One or two strands of suture material (e.g. woven polyester, monofilament nylon or fiberwire) are then inserted through the hole in the center of the toggle rod (Baltzer, Schulz, Stover, Taylor & Kass, 2001; Wardlaw & McLaughlin, 2012). The suture may be attached to the toggle by inserting a loop of suture through the hole in its center and then placing the ends of the suture back through the loop to lock the suture in place (McLaughlin, 1995; Wardlaw & McLaughlin, 2012). The toggle rod is inserted through the hole drilled in the acetabular fossa, and positioned against the medial acetabular wall by pulling the ends of the sutures (McLaughlin, 1995; Wardlaw & McLaughlin, 2012). The free ends of the sutures are then passed through the hole in the femoral head and neck, exiting near the third trochanter, being the passage facilitated by using a fine-gauged wire loop or other available instrument (Wardlaw & McLaughlin, 2012). The sutures are secured to the femur by drilling another hole through the lateral femoral cortex, passing one end of the suture through the hole and tying it to the other end (McLaughlin, 1995) Alternatively, the sutures can be secured by tying them to a sterile polypropylene button or a second toggle rod (Wardlaw & McLaughlin, 2012). While the hip is held in a reduced position, the suture is tied (McLaughlin, 1995; Wardlaw & McLaughlin, 2012). An appropriately tight suture should not allow subluxation of the hip but should also allow good range of motion for hip flexion and extension (Wardlaw & McLaughlin, 2012). Although toggle rod fixation can be used as a single technique, this method may be augmented by capsulorrhaphy or prosthetic capsule technique (Wardlaw & McLaughlin, 2012). Complications of toggle rod fixation include premature suture breaking, failure of the toggle pin, joint reluxation, injury to the rectum, sciatic nerve damage, articular cartilage damage and transient lameness approximately 2 months after surgery, due to late suture failure (McLaughlin, 1995; Kiliç et al., 2002; Wardlaw & McLaughlin, 2012).

Studies revealed a reluxation rate of 11%, occurring within the first two weeks after surgery, and 81% of patients had little or no long-term lameness (Demko et al., 2006; Wardlaw & McLaughlin, 2012).

3.3.5 – Transposition of the sacrotuberous ligament

Bone tunnels are drilled in the femur, from the *fovea capitis* of the femoral head to the greater trochanter (6mm in diameter) by means of a cannulated drill guided by a kirschner wire, and through the central part of the acetabular fossa. A cortical screw is placed in the greater trochanter, distal to the femoral tunnel (Kiliç at al., 2002). The insertion site of the sacrotuberous ligament, between the tuber ischii and the sacrum, is cut with a fragment of ischial bone (approximately 1cm in length and 0,7cm in width and depth) using a small size osteotome (Kiliç at al., 2002). The ligament is then isolated, taking care to avoid injury to the sciatic nerve as it runs under the sacrotuberous ligament, and the fragment of ischial bone is trimmed (Kiliç et al., 2002; Wardlaw & McLaughlin, 2012). Two small holes are drilled in this fragment to allow placement of two polyglactin sutures, that are passed through these holes to guide the ligament (Kiliç at al., 2002). These sutures are attached to a cerclage guide wire and the ligament is passed from medial to lateral through the acetabular fossa hole (Kiliç et al., 2002; Wardlaw & McLaughlin, 2012). The same cerclage wire is then directed into the tunnel from the *fovea capitis* to the greater trochanter, and the sacrotuberous ligament, along with the sutures, is passed through the femoral tunnel (Kiliç et al., 2002; Wardlaw & McLaughlin, 2012). The ligament is then pulled tightly through the femoral tunnel until the femoral head is relocated within the acetabulum, and when the joint is in its normal anatomical position, the suture is tightened firmly and knotted around the screw (Kiliç at al., 2002).

Studies show that all patients regained full limb function within two months postoperatively. This technique could be used in patients suffering from all types of hip luxation (Kiliç at al., 2002).

3.3.6 – Extra-articular iliofemoral suture placement

A number of extra-articular techniques have been described (Slocum & Devine, 1987; Mehl, 1988; Meij, Hazewinkel, & Nap, 1992; Martini, Simonazzi, & Del Bue, 2001) and, despite these differ both in the surgical technique and materials used, they all include a common mechanism for maintaining joint stability which is stabilizing the joint by preventing external rotation and adduction of the femur (Martini et al., 2001).

After blood clots, fibrin, granulation tissue and remnants of the ligament of the femoral head and joint capsule are cleared from the acetabulum, the luxation is reduced and capsulorrhaphy performed if possible (Martini et al., 2001; Wardlaw & McLaughlin, 2012). The ilium is exposed cranial to the acetabulum, and a hole is drilled into the ilium from lateral to medial 1 to 2 cm cranial to the acetabulum (Martini et al., 2001). A second hole is drilled through the femur, distal to the insertion site of the gluteal muscles at the base of the greater trochanter, from caudal to cranial, and suture material is passed from lateral to medial through the hole in the ilium (Martini et al., 2001; Wardlaw & McLaughlin, 2012). A curved hemostat is placed under the ventral edge of the ilial body to grasp the suture and bring it to the lateral side of the ilium (Wardlaw & McLaughlin, 2012). The dorsal end of the suture is then pushed through the femoral tunnel in a craniocaudal direction and the other end is passed from cranial to caudal under the gluteal muscles to bring both suture ends to the caudal side of the femur (Martini et al., 2001).

The most important aspect of the surgery is the knotting of the suture (Martini et al., 2001), because good stability is only obtained with correct femoral position and tension; therefore, suture ends must be tied with the femur abducted and internally rotated, resulting in maximal coaptation between the acetabulum and the femoral head (Martini et al., 2001; Wardlaw & McLaughlin, 2012). The stability of joint is tested by adducting and pushing the femur in a craniodorsal direction (Martini et al., 2001).

An alternative method for placing the suture, which avoids drilling tunnels in the ilium and femur is described and consists in anchoring the suture cranially in the tendon of origin of the psoas minor muscle and caudally to the tendon of insertion of the middle gluteal muscle (Mehl, 1988).

Studies show that during the follow-up period, reluxation did not occur, no complications associated with the surgical technique were encountered, patients started weight-bearing from 1 to 10 days postoperatively and the period of lameness ranged from 7 to 30 days, with an average of 20 days (Martini et al., 2001).

3.3.7 – Fascia Lata loop stabilization

This is another similar technique to toggle rod fixation, except that fascia lata is used instead of suture material (Wardlaw & McLaughlin, 2012). Holes are drilled in the acetabular fossa and femoral head and neck, as described for toggle rod fixation. A 1cm wide strip of fascia lata is harvested and passed over the dorsal aspect of the ilium, avoiding injury to the sciatic nerve, and through the predrilled holes in the acetabulum and femoral neck. The femoral head is reduced and the two ends of the fascial strip are sutured together near the third trochanter (Wardlaw & McLaughlin, 2012). Capsulorrhaphy is performed if possible and neither slings or external support is necessary postoperatively (McLaughlin, 1995; Wardlaw & McLaughlin, 2012).

One retrospective study evaluating the fascia lata loop technique in 10 dogs and 2 cats reported good results with 92% of coxofemoral luxations successfully reduced and stabilized (Lubbe & Verstraete, 1990).

3.3.8 – Femoral head and neck excision arthroplasty

Femoral head and neck excision arthroplasty consists in the surgical removal of the femoral head and neck and it is described as a salvage procedure ideally reserved for canine patients less than 25 kg and feline patients (Holsworth & DeCamp, 2003). It is indicated when closed or open techniques are not an option or are unsuccessful in maintaining reduction, treatment of recurrent hip luxation, concomitant severe fractures of the acetabulum or femoral head and neck, severe OA or total hip replacement is not an option (Wardlaw & McLaughlin, 2012; Harper, 2017).

The prognosis is generally good to excellent with proper technique, patient selection, and absence of complications (Bordelon, Reaugh, & Rochat, 2005)

3.3.9 – Total hip arthroplasty

Total hip arthroplasty is also described as salvage procedure recommended in patients larger than 20 kg (Holsworth & DeCamp, 2003). It is used in cases of chronic luxation, severe OA and damage to the femoral head (Wardlaw & McLaughlin, 2012). In patients with severe fibrosis around the joint, total hip arthroplasty is not possible and FHNEA is required (Holsworth & DeCamp, 2003).

As in FHNEA, the prognosis is generally good to excellent with proper technique, patient selection, and absence of complications (Bordelon et al., 2005).

4 – STABILIZATION OF VENTRAL LUXATIONS

When closed reduction is not possible or ineffective in maintaining reduction, an open approach is required for stabilization of ventral luxations (Holsworth & DeCamp, 2003). In this case, a dorsal approach to the hip joint is recommended for adequate acetabular exposure (Johnson, 2014). Reduction of the femoral head into the acetabulum is obtained by abducting the hindlimb and applying traction on the limb and countertraction on the ischiatic tuberosity (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012).

Suture of the dorsal joint capsule alone is insufficient to maintain reduction and prosthetic capsule technique or toggle rod stabilization can be used to enhance joint stability (Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012). The suture limits caudal but not ventral displacement of the femoral head; therefore, if ventral instability remains, the ventral acetabular ligament can be sutured to augment joint stability (Holsworth & DeCamp, 2003;Wardlaw & McLaughlin, 2012). Alternatively, an autogenous iliac crest shelf graft can be used to augment the ventral acetabular rim to restore ventral joint stability (Holsworth & DeCamp, 2003 ;Wardlaw & McLaughlin, 2012). Trochanteric transposition is not recommended for stabilization of this type of luxation (Wardlaw & McLaughlin, 2012).

5 – TREATMENT OF DOGS WITH PRE-EXISTING JOINT DISEASE

Neither closed or open reduction is advisable in patients with moderate to severe pre-existing coxofemoral disease (e.g. hip dysplasia, joint laxity) since the outcome is poor (Holsworth & DeCamp, 2003). Reluxation and persistent lameness were common in patients that had reduction procedures performed and 65% of cases reduced required later salvage procedures (Basher et al., 1986; Holsworth & DeCamp, 2003).

6 – POSTOPERATIVE CARE

Postoperative care includes confinement and exercise restriction for 4 to 6 weeks to allow soft tissue healing and periarticular fibrosis to occur (Wardlaw & McLaughlin, 2012).

Range of motion must be restored without causing reluxation of the joint and cryotherapy and Nonsteroidal anti-inflammatory drugs are used to minimize inflammation in the early postoperative period (Roush & Renberg, 2015). Muscle strengthening begins with walking on a level surface or a downhill grade and external rotation and adduction should be avoided during the healing phase. Activity level is gradually increased on a daily basis, starting with controlled leash walks or underwater treadmill (Roush & Renberg, 2015). Aggressive activities such as jogging, swimming or uncontrolled play are limited until the joint has completely healed, which may take up to 3 months after reduction, depending on the degree of tissue damage (Roush & Renberg, 2015).

Patients should be monitored closely for any signs of reluxation, lameness, hip pain and reduced function (Wardlaw & McLaughlin, 2012). Radiographic evaluation of the joint through all postoperative period is necessary to confirm reduction, monitor implant complications and development of OA (Wardlaw & McLaughlin, 2012). Bilateral luxations require a meticulous postoperative care including towel support under the lower abdomen when outdoors, strict inactivity and avoidance of stairs (DeCamp, 2016).

7 – PROGNOSIS

The prognosis is fair to good if reduction and stability are achieved soon after trauma (Wardlaw & McLaughlin, 2012). Results do not appear to favour any surgical technique.

A long-term study (8 to 156 months follow up) of 64 dogs treated for coxofemoral luxation using various techniques including closed reduction and Ehmer sling, extracapsular suture stabilization, transarticular pinning, toggle rod stabilization, ischioilial pinning and FHNEA showed that lameness was absent in 62% of patients but 8% to 20% were severely lame (Bone et al., 1984; Evers et al., 1997; Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012;

DeCamp, 2016). Pain was present during palpation in 48% of cases, crepitus in 32% and range of motion in the affected joint was normal in 92% of patients. Studies also reported that the presence of concomitant injuries and delayed treatment for longer than 3 days did not result in worse prognosis. In approximately 55% to 62% of cases there was radiographic evidence of OA at a long term, more pronounced in heavier dogs (Bone et al., 1984; DeCamp, 2016; Evers et al., 1997; Holsworth & DeCamp, 2003; Wardlaw & McLaughlin, 2012).

Owners report that patients returned to best limb function 2,3 months after closed reduction, 4.2 months after open reduction and 1.7 months after a FHNEA (Basher et al., 1986). The average period before returning to stable functional status after closed or open reduction was 8 weeks, with 62% to 68% of patients being able to walk normally (Bone et al., 1984; Evers et al., 1997; Holsworth & DeCamp, 2003; DeCamp, 2016;).

The greatest complication is reluxation and the presence of OA, and hip dysplasia lowers the chance of success in both open and closed reduction techniques (DeCamp, 2016; Denny & Butterworth, 2000).

Studies indicate that success rate is about 30% to 60% for closed reduction (Wardlaw & McLaughlin, 2012; Fossum, 2013; Rochat, 2016). Studies show that attempts at closed reduction do not reduce the success of later open reduction procedures (Basher et al., 1986; Bone et al., 1984; DeCamp, 2016). If the hip stays reduced for 3 weeks, the prognosis is excellent unless another trauma occurs or if there is underlying hip laxity (DeCamp, 2016).

Regarding open reduction, the prognosis varies with the stability achieved after reduction and with time interval between luxation and reduction. If reduction and stability are achieved soon after injury with adequate stability, the prognosis is good and normal function can be expected in approximately 85% of patients (Fox 1991; McLaughlin 1995; Wardlaw & McLaughlin, 2012; Fossum, 2013; DeCamp, 2016).

8 – COMPLICATIONS

Complications associated with surgical repair of coxofemoral luxations include surgical wound infection; septic arthritis; reluxation caused by several factors (e.g. implant failure, poor decision making both preoperatively and intraoperatively, technical errors during surgery, inadequate postoperative care) and, less commonly, sciatic neuropraxia (Table 1) (Rochat, 2016).

Table 1 – Complications reported in literature (1996 – 2013) after open reduction of traumatic coxofemoral luxations in dogs. (Adapted from: Rochat, 2016)

Reference	Technique	Number of cases	Complication rate	Common complications
Ash et al., 2012	Modified toggle rod using TightRope	9 (4 cats, 5 small dogs)	11%	Incisional swelling
Rochereau & Bernardé, 2012	Capsulorrhaphy and deep gluteal tenodesis	46 dogs and 19 cats (26 dogs and 8 cats followed long term	12%	Screw placement errors Seroma Dehiscence
McCartney et al., 2011	Transacetabular pin	70 dogs	6% major 45% minor	Incisional swelling and discharge Insufficient reduction
Venturini, Pinna, & Tamburro, 2010	Combined intra- and extra-articular technique	2 dogs	None	Not applicable
Demko et al., 2006	Toggle rod	62 dogs	26%	Reluxation (11.2%)
Ozaydin et al., 2003	Sacrotuberous ligament transposition	10 dogs (experimental study)	None	All markedly lame initially, with varying degrees of resolution
Martini et al., 2001	Antirotational suture	14 dogs	None	Not applicable

8.1 – Surgical Wound Infection

Surgical wound infections are the most common cause of postoperative morbidity, with overall rate ranges from 5.1% to 5.8% in small animal surgical practice (Vasseur, Levy, Dowd, & Eliot, 1988; Eugster, Schawalder, Gaschen, & Boerlin, 2004). In most veterinary studies, surgical wounds are defined as infected if there is purulent discharge from the wound, within 14 days after surgery, or there are typical clinical signs of infection such as redness, pain, swelling and heat (Laitinen-Vapaavuori, 2016).

According to veterinary studies, factors shown to be associated with higher risk of surgical wound infections include patient-related factors: age, obesity, intact males and animals with endocrinopathy (Nicholson, Beal, Shofer, & Brown, 2002), and operation-related factors: skin antisepsis, preoperative hair clipping (Brown, Conzemius, Shofer, & Swann, 1997) preoperative skin preparation, duration of surgery (Brown et al., 1997; Vasseur et al., 1988; Eugster et al., 2004), duration of anesthesia (Nicholson et al., 2002; Eugster et al., 2004; Owen, Gines, Knowles, & Holt, 2009), antimicrobial prophylaxis and surgical drains (Laitinen-Vapaavuori, 2016).

As previously mentioned, surgical site preparation (preoperative clipping, skin antisepsis and skin preparation) is an important operation-related risk factor. A recent meta-analysis concluded that preoperative cleansing with chlorhexidine is superior to povidone-iodine in reducing postoperative wound infections after clean-contaminated surgery (Noorani, Rabey, Walsh, & Davies, 2010).

Diagnosis of surgical wound infection is based on clinical signs, both local and systemic, and positive bacterial culture from the infection site (Laitinen-Vapaavuori, 2016).

Treatment consists of surgical drainage or wound debridement, depending on the extent of soft tissue or bone involvement, selection of adequate antimicrobials, based on bacterial culture results, and pain relief. The prognosis depends on the location and extent of the wound infection and the involved pathogen. Prognosis is generally good for superficial infections involving the skin and subcutaneous tissues; however, if involving deep tissues or bone, it can negatively affect the outcome of the surgery by prolonging the recovery period and causing discomfort to the patient (Laitinen-Vapaavuori, 2016).

8.2 – Septic Arthritis

As a complication of orthopaedic surgery, septic arthritis is a bacterial infection of the synovial structures. Bacterial invasion of joints during orthopaedic surgery is most frequently caused by direct contamination during surgery, but may also result from postoperative haematogenous origin or local spread from adjacent tissues (Innes, 2016). The most commonly isolated bacteria in bacterial infective arthritis in dogs are *Staphylococcus intermedius, Staphylococcus aureus* and *β-hemolytic Streptococcus spp.* (Bennett & Taylor, 1988; Marchevsky & Read, 1999; Clements et al., 2005; Innes, 2016).

Risk factors associated with bacterial infective arthritis can be divided between procedure-based and patient-based. Procedure-based factors include the placement of a biomaterial closer or in the joint (Vasseur et al., 1988; Brown et al., 1997; Casale & McCarthy, 2009), open arthrotomy, prolonged surgery time and spread of infection from adjacent tissues. Patient-based factors include previous surgery in the same anatomic region (Olmstead, Hohn & Turner, 1983), reduced blood supply and immunosuppression (Innes, 2016).

Diagnosis is based on clinical signs and typically includes pain and loss of function, with moderate to severe lameness of acute onset. Other signs include joint swelling, redness, heat and draining sinus (Innes, 2016).

Although diagnostic imaging is not required, radiographs may help investigate the presence of contributing factors (e.g. implant failure) and document secondary changes (e.g. soft tissue swelling centred on the joint line, joint effusion and osteophytosis). In the coxofemoral joint, to correctly evaluate synovial fluid volume, comparison of the width of joint spaces between bilateral joints must be performed (Innes, 2016).

Treatment involves several approaches, which can be combined. Systemic antibiotic therapy, based on culture and sensitivity test, is the standard treatment (Marchevsky & Read, 1999; Innes, 2016) and a minimum of 28 days of therapy is recommended. Repeated arthrocentesis and synovial fluid analysis at the end of that period if required to access effectiveness of treatment (Innes, 2016).

Studies report that no convincing evidence supports surgical intervention, unless there is gross contamination of the joint or an infected implant (Clements et al., 2005; Marquass et al., 2010). Although medical and/or surgical management are usually successful in resolving infection, they are frequently unsuccessful in restoring full joint function (Clements et al., 2005).

8.3 – Reluxation

Reluxation can occur for a number of reasons including poor case selection; poor intraoperative decision making; technical errors, which vary with the surgical procedure; implant failure and inadequate postoperative care (Rochat, 2016).

Risk factors include duration of the luxation, as maintaining reduction in chronic luxations is more difficult, and previous failed attempts at reduction. Both factors aggravate the damage to the joint capsule and surrounding soft tissues, lead to oedema, inflammation and destruction of supporting soft tissue (Rochat, 2016).

Diagnosis is based on recurrence of clinical signs: changes in gait; increased pain beyond levels expected after surgery; excessive swelling around the hip joint; altered limb length; asymmetry of the hips, loss of normal spatial alignment of the greater trochanter, ischiatic tuberosity and iliac crest; and confirmed through radiographic examination (Wardlaw & McLaughlin, 2012; Rochat, 2016; DeCamp, 2016).

Treatment of reluxation begins by reassessing the patient for risk factors such as hip dysplasia, concurrent injuries and pre-existing conditions that created an imbalance between the demands placed on the hip and the biomechanical properties of the repair. Assuming open reduction is still appropriate and technical errors can be corrected, the original technique can be reapplied. However, if technical errors were not obvious, using another technique or a combination of techniques is advised to achieve success and avoid another reluxation (Rochat, 2016).

Adequate analgesia in the postoperative period is of maximum importance, to avoid undesirable activity and uncontrolled motion from the patient, and should include NSAIDs, opioids, cryotherapy and local anaesthesia (Rochat, 2016).

Salvage procedures (Total hip arthroplasty or FHNEA) should be considered if factors that predispose the repair to failure (e.g. extended damage to the articular surfaces, infection, lack of owner and patient compliance) are identified during evaluation (Denny & Butterworth, 2000; Holsworth & DeCamp, 2003; Rochat, 2016).

8.4 – Neuropraxia

Neuropraxia is defined as a peripheral nerve injury causing transient loss of nerve conduction without axonal disruption, with or without demyelination (Comito, 2016). Sciatic neuropraxia results from damage to the sciatic nerve, as it runs caudally over the hip, medial to the greater trochanter, craniomedial to the tuber ischii and then distally, caudal to the femur on the lateral side of the adductor muscle (Evans & de Lahunta, 2010). Nerve injury is rare with hip luxation and usually occurs iatrogenically, during surgical stabilization of the luxated hip (Fox, 1991).

Risk factors include improper surgical approach (e.g. direct or indirect damage to the sciatic nerve), improper surgical technique (e.g. poor hemostasis, poor lightning of the surgical field and technical errors with implants or instrument placement), chronic luxation and muscle spasm or concurrent injuries that are leading to exaggerated retraction and nerve damage (Andrews, Liska, & Roberts, 2008; Rochat, 2016).

Neuropraxia results in some degree of proprioceptive and motor dysfunction, for a short period of time, and diagnosis can only be made if the patient is weight-bearing (Rochat, 2016). Radiographic assessment is recommended to evaluate if surgical implants are impinging the sciatic nerve and causing neurologic signs (Rochat, 2016).

Conservative management is indicated if the only abnormality found is proprioceptive diminution or loss, that cannot be attributed to the surgical implant placement, and surgical exploration is indicated if implants are judged to be near or in the way of the sciatic nerve. In these cases, revision of the implants or stabilization technique should occur as soon as possible (Rochat, 2016).

Although this complication is almost always temporary in small animals, with a quick and complete recovery if nerve damage does not disrupt the nerve axon or its sheath, efforts should be made to prevent it because abnormal weight bearing may predispose to reluxation (Andrews et al., 2008; Rochat, 2016). Spontaneous recovery of neuropraxia is expected within 1 or 2 weeks after injury; however, if demyelination has occurred, recovery may take longer (Comito, 2016). Patients that present a delayed neuropathy (months to years after surgery) should be radiographically assessed to determine if there was implant migration, which is now irritating the sciatic nerve and causing neurologic signs (Issack & Helfet, 2009; Rochat, 2016).

9 – OBJECTIVES

The objectives of this study were to describe and evaluate a modification of the extra-articular iliofemoral suture placement technique originally described by Slocum & Devine (1987), by applying two bone anchors and a crimping system for the treatment of craniodorsal coxofemoral luxations in dogs, and report associated complications. This technique is performed by a veterinary surgeon at Hospital Veterinário do Oeste since 2015.

III – EXTRA-ARTICULAR ILIOFEMORAL SUTURE PLACEMENT WITH BONE ANCHORS

1 – MATERIALS AND METHODS

1.1 – Study design

The present study was designed as a sequential case series in dogs with coxofemoral luxation.

1.2 – Inclusion criteria

Inclusion criteria were dogs with radiographic diagnosis of craniodorsal coxofemoral luxation presented for consultation at HVO in Lourinhã, between August 2015 and May 2017.

The surgical procedure performed was extra-articular iliofemoral suture placement with bone anchors and at least 4 weeks follow-up were required.

Seven dogs were included in the study.

1.3 – Clinical variables

Data obtained included age, breed, sex, body weight, cause of trauma, affected hindlimb, direction of luxation, presence of concomitant injuries, time interval between hip luxation and surgical procedure, implant type, pre-and postoperative management, antimicrobial therapy, pain management, postoperatively complications and time interval between surgery and weight - bearing.

1.4 – Radiographic assessment

Standard ventrodorsal and lateral projections of the pelvis were performed under sedation with Butorphanol (Alvegesic, Dechra), dosage 0,1-0,2 mg/kg, and Dexmedetomidine (Dexdomitor, Orion Pharma), dosage 0,005-0,01 mg/kg, by IV injection. Such procedure was performed before surgery, to confirm and assess the direction of luxation and report the presence of concomitant fractures. Postoperative radiographic assessment of the hip joint was performed immediately after surgery, while the patient was still under anaesthesia, to confirm reduction and surgical implants positioning (bone anchors and crimp clamp).

1.5 – Preoperative management

Pre-anaesthetic blood tests (complete blood count, electrolytes and biochemistry panel) were performed in all patients. Fasting prior pre-anaesthetic medication was requested to the owners – 8 to 10 hours.

All patients were premedicated with Midazolam (Labesfal), dosage 0,2 mg/kg, and Methadone (Semfortan, Dechra), dosage 0,3-0,4 mg/kg, by IM injection. Acepromazine (Calmivet, Vetoquinol), dosage 0,01-0,05 mg/kg, was added to premedication in cases where the patient was exhibiting anxiety. Induction was performed with Propofol (Lipuro, B. Braun), dosage 1-4 mg/kg IV, and Diazepam, dosage 0,5 mg/kg IV. Isoflurane, an inhaled anaesthetic, was used to maintain anaesthesia.

Ceftriaxone (Fresenius Kabi), dosage 20mg/kg, was administered IV within 30 to 60 minutes before the first incision, and repeated every 90 minutes during surgery.

Anaesthesia monitoring included evaluation of circulation, ventilation and oxygenation, with the aim of ensuring proper maintenance of tissue blood flow, arterial blood oxygen concentration and ventilation. More specifically, the parameters evaluated in all surgeries were: heart rate, electrocardiogram, blood pressure, pulse quality, respiratory rate, mucous membrane colour and capnography.

IV fluid therapy was provided during the peri-anaesthetic period and consisted of isotonic crystalloid fluids (Lactated Ringer's or NaCl 0,9%) administered at a rate of 10 mL/kg/hr, which was adjusted throughout surgery according to the patient's response.

1.6 – Characterization of the surgical implants

The surgical implants used in this study were Break-off Bone Anchors and a Crimping System by SECUROS (Figure 10).

Break-off bone anchors are composed of a trocar point, a cortico-cancellous thread section, a suture spindle, a break-off point and an insertion shaft. Once the bone anchor is placed, by using a Jacob's Chuck, the insertion shaft cleaves off at the break off point and the shaft is discarded (Figure 11). After discarding the shaft, the spindle and threaded portion will remain firmly embedded in bone. To prevent the bone anchor from prematurely breaking during insertion it is advisable to readjust the chuck, advance the bone anchor further into the chuck, and grip it pass the point where it breaks.

Figure 10 – Stainless Steel Break-off Bone anchors (2.7mm, 3,5mm and 4,5mm) (A) and 100lb MNL and stainless-steel Crimp Clamps (B) by SECUROS. (Original photo)

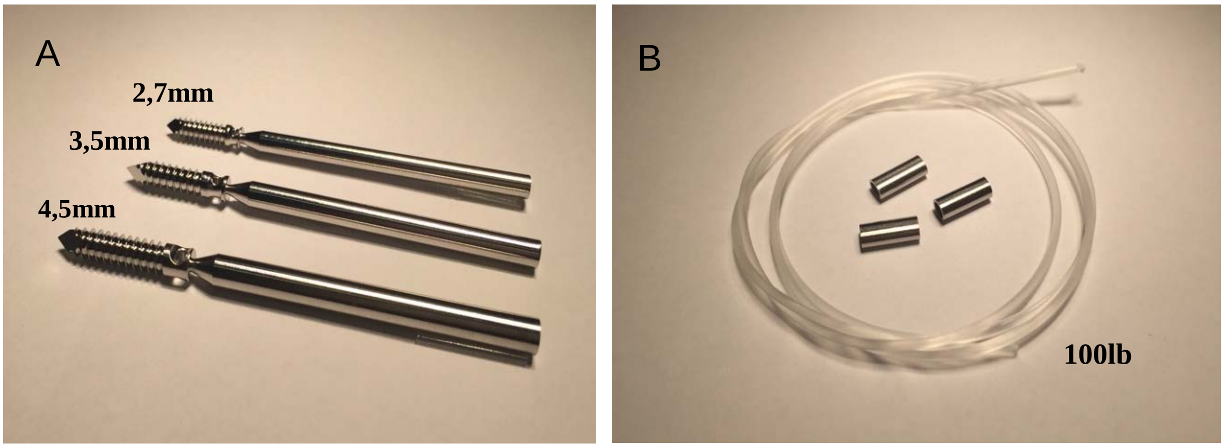
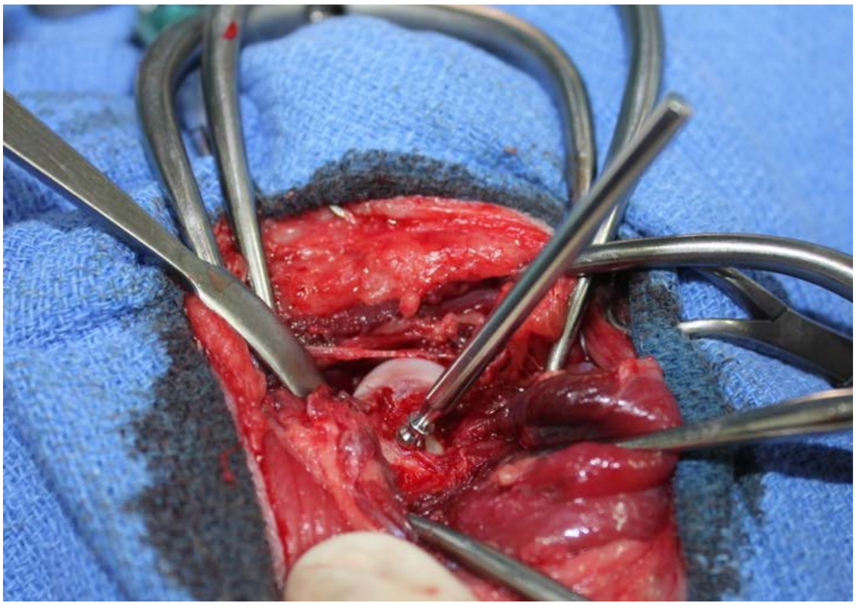


Figure 11 – Stainless Steel Break-off Bone anchors by SECUROS with shaft attached. (Original photo)



SECUROS has three sizes of bone anchors available: 2.7mm, 3,5mm and 4,5mm and it is advisable to pre-drill the anchor site with an appropriate drill bit size, according to the size of the bone anchor to be used (Table 2). The size of the bone anchor was chosen based on the dog's weight and size of the bone. The suture size was estimated according to the dog's weight (Table 2), patient's activity level and compliance (SECUROS, 2017a).

The Crimping System is composed of a monofilament nylon leader suture (size 40lb, 80lb or 100lb), stainless-steel crimp clamps, a Tensioning device and a Crimping device.

Table 2 – Bone Anchor/ MNL reference Guide by SECUROS. (Adapted from: SECUROS, 2017b)

Bone Anchor size	Drill Bit size	MNL	Dog's weight (Kg)
2,7mm	2,4mm	40lb	0 – 13,6
3,5mm	3,2mm	80lb 40lb	13,6 – 31,8 18,1 – 27,2
4,5mm	3,2mm	80lb 100lb	> 31,8 – 63,5 < 27,2 – 40,8

1.7 – Surgical technique

Surgical Asepsis

The patient's affected hindlimb was clipped from the midline of the back to the tibiotarsal articulation; the non-clipped area was wrapped with non-sterile Vetrap bandaging tape and the hindlimb was cleansed with povidone-iodine 4% foam solution (EGREMA) diluted 50% in water. Then, the patient was placed in the surgical table in lateral recumbency with the clipped limb uppermost and suspended to facilitate skin disinfection (Figure 12).

Aseptic disinfection was performed by using sterile gauze swabs immersed in povidone-iodine 10% dermic solution (EGREMA). The patient's skin was scrubbed starting in the area of the incision and working outwards to the limits of the clipped area. This cycle was repeated several times and, after a few minutes, wiping off was performed using dry sterile gauze. After the final rinse, the area was wiped again with povidone-iodine 10% dermic solution (EGREMA) and allowed to dry.

The surgeon's hands were disinfected with chlorhexidine soap 0,8% (Desinclor) and an alcohol-based gel (Sterillium Gel, Hartmann) prior to dressing and gloving. Sterile reusable gowns and disposable sterile gloves were used.

Four sterile reusable towels were firstly placed by the surgeon around the leg at the inguinal region, while the circulating assistant grasped the leg on the unprepared area and removed the suspending strip while holding the leg in position. Then, the surgeon grasped the leg in a previously disinfected area and wrapped sterile Vetrap bandaging tape around the unprepared area while holding the limb up and away from the table. The leg was then allowed to rest on the table, atop the sterile reusable towels.

Figure 12 – Positioning of the hindlimb in the surgical table for aseptic disinfection. (Original photo)

Description of the extra-articular iliofemoral suture placement with bone anchors

The surgical approach to the Hip joint was made through a curvilinear incision, cranial to the greater trochanter, from mid-body of the ilium to the proximal third of the femur (Figure 13). Then, the skin margins were retracted and attached to sterile skin towels with Backhaus towel clamps.

An incision was made through the superficial leaf of the fascia lata, along the cranial border of the biceps femoris muscle, which was retracted caudally to allow incision in the deep leaf of the fascia lata, to free the insertion site of the tensor fascia lata muscle. The incision was continued proximally between the cranial border of the superficial gluteal muscle and the tensor fascia lata muscle. The fascia lata and the attached tensor fascia lata muscle were retracted cranially and the biceps caudally (Figure 14).

Figure 13 – Schematic drawing of the surgical approach to the Hip joint (Original drawing)

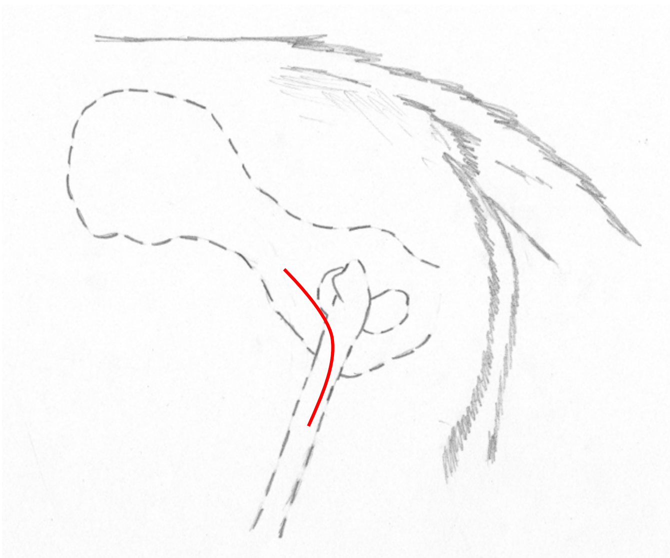
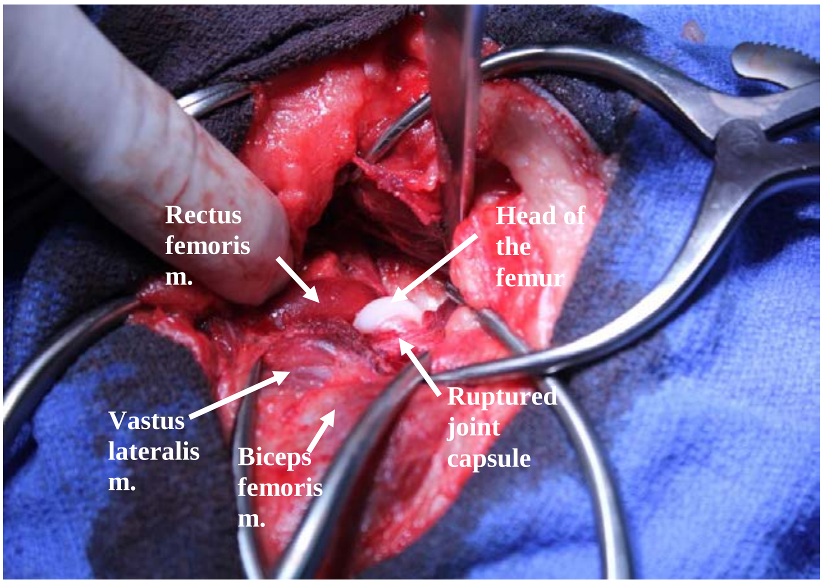
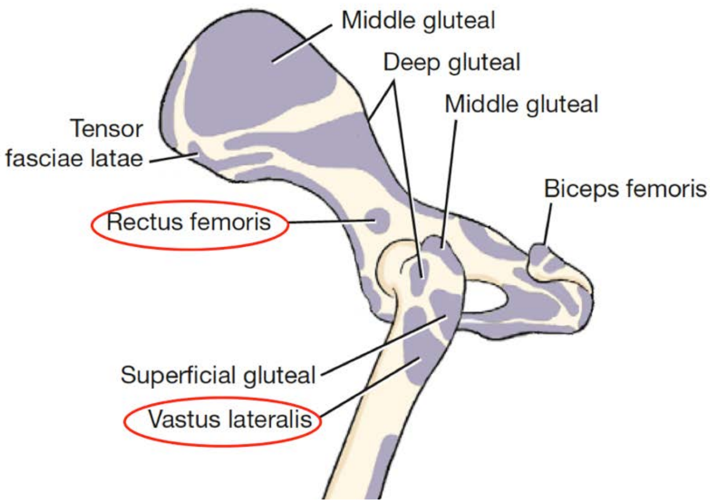


Figure 14 – Surgical approach to the Hip joint in a craniodorsal luxation. (Original photo)



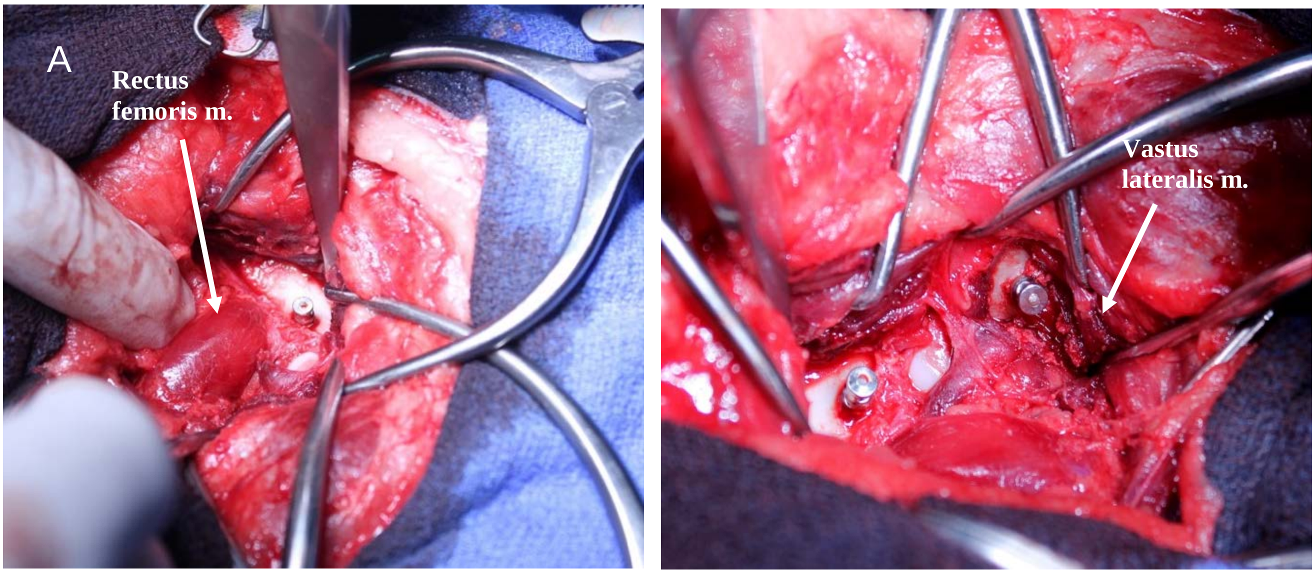
The next step was to find the origin of the rectus femoris muscle, which is located on the lateral surface of the body of the ilium, cranial to the acetabulum (Figure 15).
After previously pre-drilling, the first bone anchor was placed into the craniodorsal border of the origin of the rectus femoris muscle (Figure 16 - A).

Figure 15 – Lateral view of muscle attachments on the pelvis and hindlimb. (Adapted from: Evans & de Lahunta, 2010)



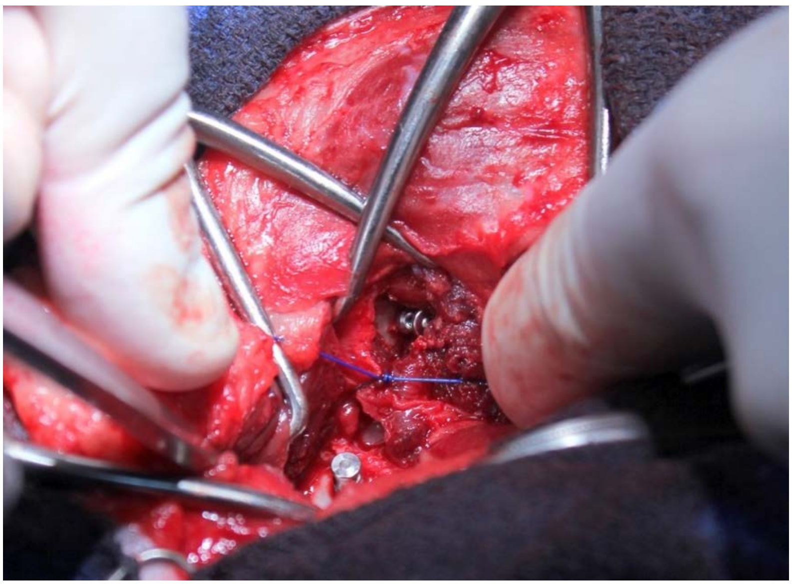
Then the origin of the vastus lateralis muscle was located, at the proximal part of the lateral lip of the caudal rough surface of the femur (Figure 15), an incision was made in the direction of the muscle fibers of the vastus lateralis muscle and the second bone anchor was placed, after previously pre-drilling, at half distance between the head of the femur and the greater trochanter (Figure 16 – B).

Figure 16 – First two steps of the extra-articular iliofemoral suture placement with bone anchors. (A) – Placement of the first bone anchor in the body of the ilium (B) – Placement of the second bone anchor in the femur. (Original photo)



The luxation was carefully reduced and capsulorrhaphy was performed with Dafilon using interrupted sutures (Figure 17).

Figure 17 – Capsulorrhaphy performed with Dafilon. (Original photo)



Then, MNL was inserted through the eyelet of the bone anchor in the ilium (Figure 18) and passed through the eyelet of the bone anchor in the femur. The two ends of the MNL were passed through the crimp clamp in the opposite direction and a Crimping device was used to crimp the crimp clamp in both ends and secure the MNL in place (Figure 19). Caution was taken not to crimp too close to the end of the tube, and 1mm was left uncrimped.

Figure 18 – MNL inserted through the eyelet of the bone anchor in the ilium. (Original photo)

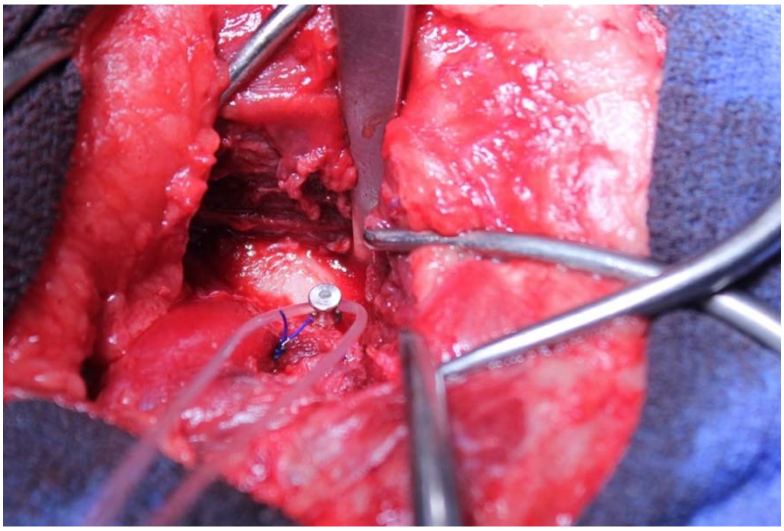
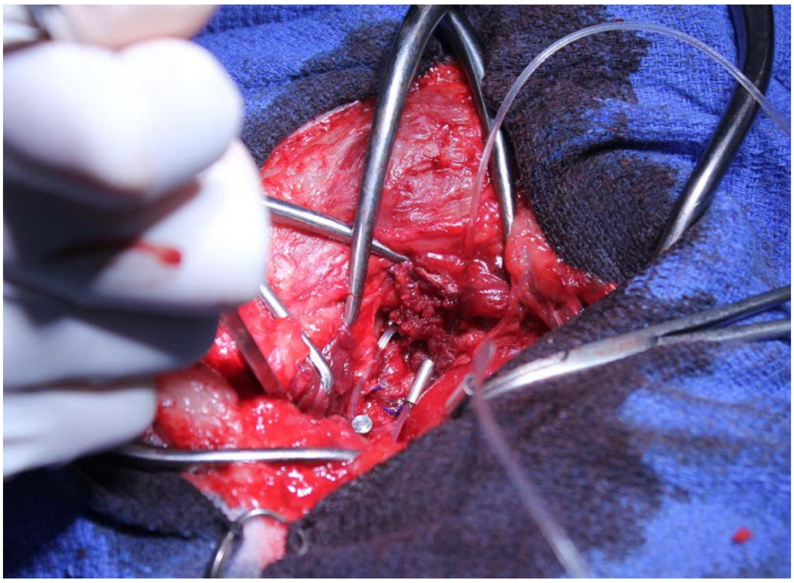
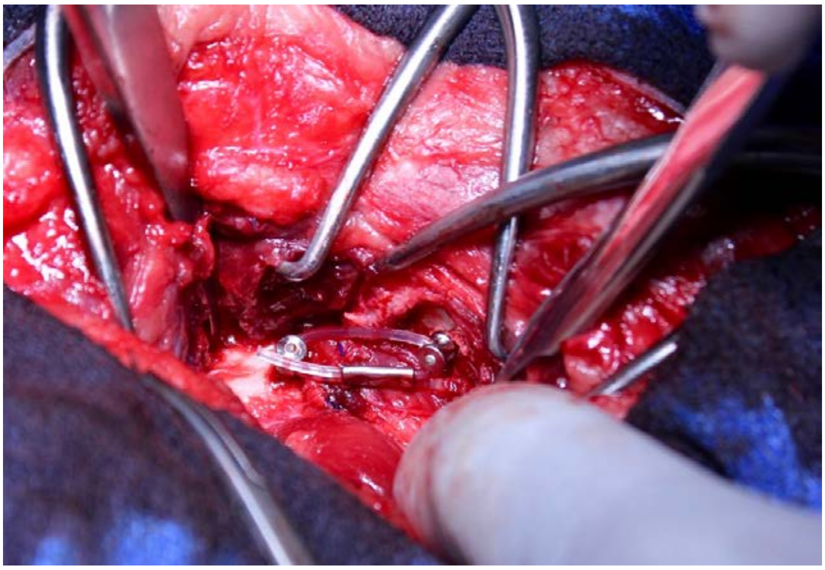


Figure 19 – Two ends of the MNL passing through the crimp clamp. (Original photo)



Tension was applied using a Tensioning device, which grips the free nylon ends and pulls them through the crimp clamp. Care was taken not to apply neither too much nor too little tension, as this is a great technical error. The free ends of the MNL were cut off, leaving a minimum of 1cm uncut, (Figure 20) and the surgical wound was closed in a routine manner.

Figure 20 – Final aspect of extra-articular iliofemoral suture placement using two bone anchors and a crimping system by SECUROS. (Original photo)



1.8 – Postoperative management

Carprofen (Rimadyl, Zoetis), dosage 4mg/kg, was administered SC after surgery unless adequate blood pressure was not maintained during the perioperative period. If hypotension occurred (Mean arterial pressure < 60 mm Hg), NSAIDs were only given at a minimum of 2 hours after surgery.

Another dose of Methadone (Semfortan, Dechra), dosage 0,3 to 0,4 mg/kg, was given to all patients 4 hours after the one previously given in premedication. In the first 24h postoperatively pain management remained with Methadone at a lower dose, dosage 0,2 to 0,3 mg/kg, and then continued with Tramadol (Labesfal), dosage 4 mg/kg, IV twice or three times daily. Ceftriaxone (Fresenius Kabi), dosage 20mg/kg, IV was maintained 24h postoperatively and then continued with Cefalexin (Ceporex, MSD), dosage 10mg/kg IM.

Cryotherapy was performed every 6 hours for 10 minutes, in the immediate postoperative period, to help control pain and inflammation. In the first three to four days postoperatively, cryotherapy was encouraged to be continued by the owners.

Dogs were typically discharged from the hospital 48 hours after surgery and oral medication was introduced consisting of Cefalexin (Cephacare, Hifarmax), dosage 20 mg/kg, two times daily for 7 days; Carprofen (Rimadyl, Zoetis), dosage 4mg/kg, once daily for 2 days and Tramadol, dosage 2-3 mg/kg, twice times daily for 7 days.

Upon discharge, the patient's home-care was discussed with the owner to allow understanding of medication, exercise restriction and wound care. Exercise restriction was advised 6 to 8 weeks postoperatively, with progressive increase of exercise. During the first week after surgery, lead exercise for five to ten minutes four times daily was recommended and in the following two weeks lead exercise was increased to ten to fifteen minutes four times daily.

Physical examination and radiographic follow-up was performed at 4 and 8 weeks postoperatively, time of final evaluation. The scoring system described by Mehl (Mehl, 1988) was used to classify the final evaluation of the patient. Patients were classified as:

– Excellent recovery: no signs of lameness, pain and crepitation during joint manipulation at clinical examination, no radiographic degenerative changes and return to preinjury level of activity;

– Good: no signs of lameness, joint only painful at maximal flexion and extension, no or slight crepitation at clinical examination, mild OA and occasional lameness after heavy exercise;

– Acceptable: intermittent lameness, joint moderately painful throughout normal range of motion, crepitation and laxity on palpation, moderate OA;

– Not Acceptable: no weight-bearing or persistent lameness, pain on joint manipulation, reluxation or severe OA.

1.9 – Complications

Type and outcome of postoperative complications was recorded. Complications were confirmed by direct visualization, physical or radiographic examination and included surgical wound infection and reluxation.

1.10 – Statistical analysis

Data analysis was performed based on descriptive statistics methods (mean, absolute frequency and relative frequency) using Microsoft Office Excel program.

2 – RESULTS

Extra-articular iliofemoral suture placement with bone anchors for coxofemoral luxation reduction was performed in seven dogs (7 coxofemoral joints). The average age of the patients at time of diagnosis was 4,7 years, with a range from 8 months to 11 years, and only one patient (14%) was less than 1 year of age. The study sample comprised 4 females (57%) and 3 males (43%) and the mean body weight was 13,21 kg with a range of 5,9 to 30 kg. Both females and males were intact.

The study comprised 4 mixed breed dogs (58%) and 1 each (14%) of the following pure breeds: Bull Terrier, Cocker Spaniel and French Bulldog (Table 3). Five dogs (71%) had the right hindlimb affected and two dogs (29%) had the left limb affected. All luxations were craniodorsal, as previously described in the inclusion criteria.

Table 3 – Identification, age, breed, sex, body weight, type of trauma, complications and time interval between luxation and surgical repair of the study cases (M – male; F – female)

Case	Age (years)	Breed	Sex	Body weight (kg)	Type of trauma	Time between luxation/repair (days)	Complications
1	4	Mixed breed	F	5,9	Cause not known	1	NO
2	2	Bull Terrier	M	30	Vehicular trauma	4	RECURRENCE
3	1	Mixed breed	M	7,7	Dog fight	7	NO
4	10	Cocker Spaniel	M	16,5	Fall from height	1	NO
5	4	Mixed breed	F	9,25	Vehicular trauma	9	NO
6	11	Mixed breed	F	14,8	Cause not known	21	RECURRENCE + SWI
7	0,7	French Bulldog	F	8,35	Cause not known	1	NO

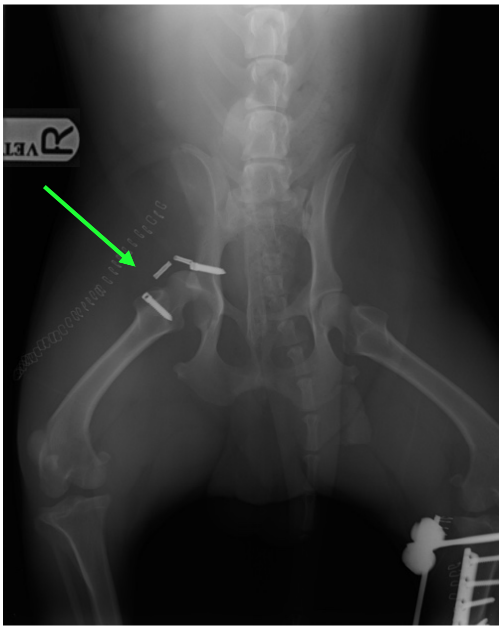
The cause of trauma was unknown in 3 (43%) of the 7 patients. Two dogs were involved in a road traffic accident (29%), one (14%) fell from a significant height and the other (14%) was involved in a dog fight (Table 2). One patient (case 2) (14%) had concomitant injuries requiring medical and surgical treatment: fracture of the left tibia and left radius.

Time interval between hip luxation and surgical procedure varied from less than 1 day to 21 days, with an average of 6,3 days, with reduction being obtained in all patients.

Postoperatively complications were registered in 2 patients (29%), and included surgical wound infection (Figure 21) and/or reluxation (Figure 22).

Figure 21 – Surgical wound infection in case 6. (Original photo)

Figure 22 – Reluxation in case 2. (Dispensed by HVO)



Reluxation occurred in case 2, seven days postoperatively, and in case 6, five days postoperatively. Case 6, besides reluxation, also developed SWI (Table 3). Clinical signs of infection (fever, redness, pain, swelling and heat) and purulent discharge from the wound were present in case 6 three days postoperatively, with suture dehiscence occurring six days postoperatively. Bacterial culture and antibiotic susceptibility test were performed and showed growth of *Enterococcus spp.* and *Streptococcus spp.* The patient stayed hospitalized until SWI was resolved, after 4 weeks of treatment with Ceftriaxone (Fresenius Kabi) and Clindamycin

(Clincina, Labesfal). Reluxation was confirmed by radiographic examination five days postoperatively, and amputation was performed.

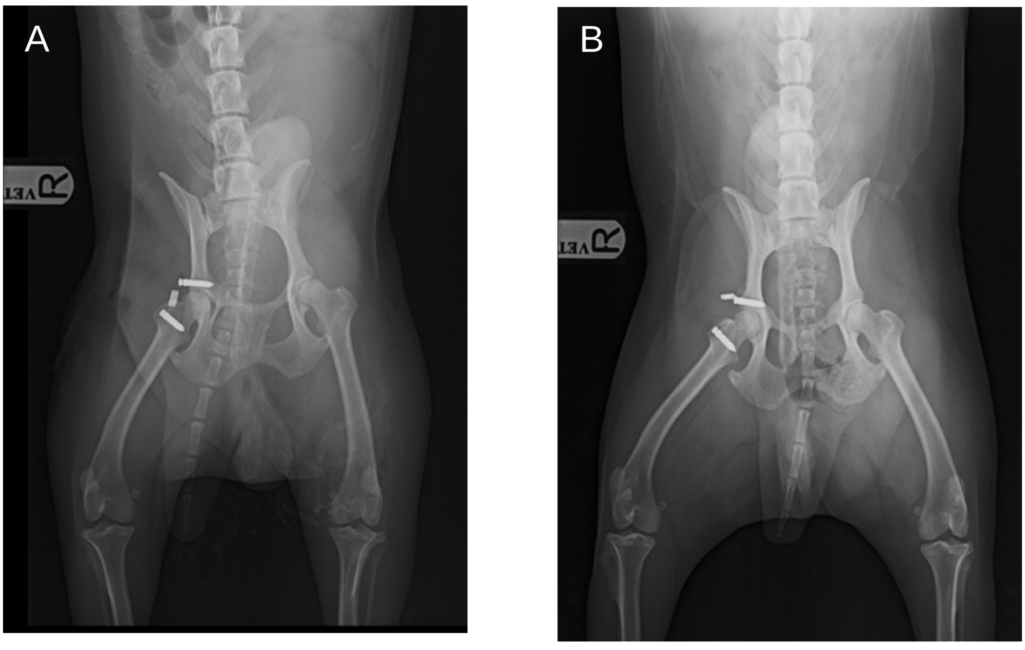
Case 2 was discharged from the hospital 48h postoperatively and returned seven days postoperatively due to the return of clinical signs of luxation.

Five patients (72%) (cases 1,3,4,5 and 7) showed no complications in early postoperative period and were discharged from the hospital 48h after surgery. These patients started weight-bearing 1 to 3 days after surgery, with mean of 1,4 days and, upon discharge, patients showed signs of mild lameness, no signs of pain, crepitation or joint laxity during passive movements of flexion-extension, adduction–abduction and external rotation movements. These patients returned seven days after surgery for re-evaluation. At 10 to 14 days for skin suture removal.

In cases 1,3,4,5 and 7 all surgical implants were adequately positioned in the radiographs obtained immediately after surgery. At 4 weeks postoperatively, patients were free from signs of lameness, pain and crepitation during joint manipulation and there were no radiographic changes in comparison to radiographs obtained immediately after surgery. At 8 weeks postoperatively, time of final evaluation, recovery was classified as Excellent, according to Mehl's scoring system (Mehl, 1988). Radiographic findings included maintenance of reduction, no signs of OA and breaking of the nylon and consequent dislocation of the crimp clamp from its previous location, as expected (Figure 23).

Case 6 was not scored and case 2 was classified as Not Acceptable, according to Mehl's scoring system (Mehl, 1988).

Figure 23 – Radiograph at 4 (A) and 8 weeks (B) postoperatively. (Dispensed by HVO)



3 – DISCUSSION

Coxofemoral luxations are a common traumatic injury seen in small animal practice, representing up to 90% of all luxations in dogs and cats (Bone et al.,1984; Basher et al., 1986; McLaughlin, 1995). Craniodorsal luxations are the most frequent, being observed in 78% of dogs (DeCamp, 2016). Literature describes two types of treatment for coxofemoral luxation in dogs: closed reduction, which has to be performed within 72 hours after trauma under general anaesthesia (Bone et al., 1984), and open reduction, divided on intra-articular and extra-articular techniques (Bone et al., 1984; Basher et al., 1986; Venturini, Pinna, & Tamburro, 2010). The two most important components of an open technique are maintenance of reduction and reestablishment of normal joint motion in the long-term. Several techniques have been described, but not all seem to be able to achieve this result (Martini et al., 2001).

Considering that intra-articular stabilization techniques may damage the articular surface and, therefore, induce arthrosis, these do not seem an ideal method of repair (Meij et al., 1992). On the other hand, extra-articular techniques, such as extra-articular nonabsorbable sutures, are reported to have good to excellent clinical results with a low rate of complications (Martini et al., 2001). The objective of extra-articular suture techniques are similar to those of an Ehmer sling, limitation of external rotation and adduction (Martini et al., 2001).

The extra-articular iliofemoral suture placement technique with bone anchors and a crimping system described in this study is a modification of a previously described technique that consists of a figure-of-eight iliofemoral suture that maintains abduction of the femur and internal rotation of the femoral head within the acetabulum (Slocum & Devine, 1987; Meij et al., 1992; Anderson et al., 1998). The modifications that we suggested in this study were: instead of drilling transosseous tunnels into the femur and acetabulum, we placed bone anchors; instead of a figure-of-eight iliofemoral suture tied with a knot, we used a MNL loop secured with a crimping system.

The success of the surgical technique relies not only on the surgeon's experience in performing it but also on the correct choice of surgical implants and suture material, which should be carefully chosen prior surgery, based on the patient's age, health, size and expected compliance of pet and owner after surgery (Soontornvipart, Nečas, & Dvořák, 2003)

The surgical implants used in this study were stainless steel supracortical Break-off Bone Anchors by SECUROS. Break-off bone anchors are stainless steel or titanium orthopaedic devices that facilitate the attachment of suture material to bone. These implants were designed to provide temporary fixation of a prosthetic material until functional healing or peri-articular fibrosis occurs and have distinct advantages compared to other techniques like transosseous tunnels, screws and washers and bone staples (Goble, Somers, Clark, & Olsen, 1994; Giles et al., 2008).

Bone anchors have the advantage of a lower profile, which helps to avoid interference and abrasion of adjacent soft tissues during joint movement; they can be more precisely and quickly placed; require less surgical exposure; are very unlikely to pull out of the bone and protect the suture by chamfering the edges of the hole through which the suture passes, thus minimizing trauma to the suture material at the suture/anchor interface (Goble et al., 1994; Beale, 2006).

Anchor release from the bone is a possible failure, although very unlikely as previously mentioned, which can be avoided by selection of the appropriate type of anchor for the type of bone presented (Beale, 2006).

Supracortical bone anchors are those that are sited above the surface of the bone, leaving a portion above the surface of the bone, typically the eyelet of the anchor (the part that holds the suture material). This gives them the advantage of placing the suture after the placement of the bone anchor. When applying two bone anchors, regarding orientation, they have to be in the same plane while perpendicular to the direction of the suture material. Regarding spacing, it must be the diameter of a single 4.5mm, 3.5mm or 2.7mm bone anchor (SECUROS, 2017a).

Suture anchors are very commonly used for joint stabilization and tissue reattachment in human patients (Beale, 2006). These orthopaedic implants are quite expensive for human use, but there are more affordable ones designed for the veterinary market (Beale, 2006). Results obtained in this study confirmed that bone anchors are an effective and reliable method for attaching suture material to bone and they also provide a practical way to restore stability of the coxofemoral joint.

Studies performed on the extra-articular stabilization of canine cranial cruciate ligament deficient stifles have compared the mechanical properties of different types of orthopaedic suture materials used for extra-articular stabilization and the application of either a knot or a crimp clamp to secure and maintain tension on the loop (Caporn & Roe, 1996; Anderson et al., 1998; Sicard, Hayashi, & Manley, 2002; Moores, Beck, Jespers, Halfacree, & Wilson, 2006; Vianna & Roe, 2006; Burgess, Elder, Mclaughlin, & Constable, 2010; Ledecky et al., 2012).

The ideal suture material properties should include: high tensile strength, biologically inert, aseptic, easily handled, inexpensive, excellent knot security, knot compactness and ability to withstand cyclical and tensile loading (Banwell, Kerwin, Hosgood, Hedlund, & Metcalf, 2005).

The most commonly used material by surgeons is MNL because it fulfils many of these requirements (Burgess et al., 2010). MNL can undergo significant elongation when tied and form bulky knots that may increase patient morbidity by causing tissue irritation (Anderson et al., 1998; Sicard et al., 2002). When compared with polyamide sutures, MNL is stronger, stiffer and elongates less (Ledecky et al., 2012) but is less stronger, less stiffer and elongates more when compared to Polyethylene-based sutures (Burgess et al., 2010). As a disadvantage, Polyethylene-based suture material is more expensive than MNL.

Studies on joint capsule and ligament healing after coxofemoral luxation and reduction demonstrated that by day 14, fibrous reaction of the joint capsule and healing of the ligament of the femoral head had occurred (McLaughlin & Tillson, 1994; Martini et al., 2001). So, regardless of the choice of suture material, it must maintain joint stability for a minimum of two weeks, which is the time until the soft tissues have healed with maturation of scar tissue and reformation of the joint capsule. Once this has occurred, the anatomic shape of the hip joint and fibrosis of the joint capsule hold the femoral head in place.

Additionally, as suture material size increases, knots may become more difficult to manually tighten, which increases the risk of knot slippage (Caporn & Roe, 1996; Anderson et al., 1998). As an alternative to knotting, crimping is a described technique to knot fixation, which has the potential of allowing easier maintenance of initial tension and stiffness, decrease loop elongation and eliminate the bulky knot (Anderson et al., 1998; Vianna & Roe, 2006). Crimping MNL increases loop stiffness and decreases loop elongation (Burgess et al., 2010). Different studies have reported contrary results, ones report that crimped MNL loops are significally weaker than knotted loops (Sicard et al., 2002; Burgess et al., 2010) and others the opposite (Peycke, Kerwin, Hosgood, & Metcalf, 2002; Vianna & Roe, 2006; Roe, Kue, & Gemma, 2008). These contradictory results may be due to a difference in operator grip strength, knotting ability and differences in methodology (Moores et al., 2006). All things considered, the method of loop fixation depends on the surgeon’s preference (Ledecky et al., 2012). In this study, we chose to apply a crimping system to maintain tension on the loop because the greatest advantage over knotted loops is that crimped loops ensure optimal tension of the suture, are stiffer and resist static and cyclic loads more effectively before becoming permanently elongated (Vianna & Roe, 2006). Caution must be taken to leave 1 mm uncrimped, as crimping too close to the end of the crimp clamp may increase abrasion and failure. Crimp marks should have uniform shape across the short axis of the crimp clamp, they must be evenly spaced apart from each other and there must be two crimp marks.

Potential technical errors could have occurred in the surgical technique described in this study: improper anchor placement in the femur or acetabulum, improper positioning of the limb when tightening the suture, failure of the crimping system, excessive laxity of the suture and excessive tightness of the suture and consequent suture breakage (Rochat, 2016).

To guarantee that technical errors do not occur:

– Anatomic landmarks were carefully reviewed before surgery;

– Pre-drilling was performed away from the edge of bone with several millimetres of surrounding bone;

– Larger bone anchors were used to avoid bone anchor failure and prevent suture breakage;

– After suture placement, tension was checked with the limb in neutral position to ensure the suture was not too tight;

– When tightening the suture, the limb was in neutral rotation, with the desired sagittal plane position, since excessive internal or external rotation could result in failure;

In general, the amount of tissue trauma is proportional to pain, secondary to increasing levels of circulating cytokines (Kristiansson, Saraste, Soop, Sundqvist, & Thörne, 1999). Orthopaedic surgery can result in moderate-to-severe postoperative pain (Mathews et al., 2014) and to optimize pain management and improve the safety of anesthesia, a perioperative approach is advised (Hellyer et al., 2007).

Pain management includes a preemptive approach, analgesic administration before, during and after a painful stimulus, and a multimodal approach, by selecting drugs from different analgesic classes that act by different mechanisms (Vedpathak et al., 2009). Additionally, because anxiety and fear can amplify pain, and physical restraint may contribute to pain, tranquilizers should be used for anxious or fearful animals undergoing hospital procedures (Hellyer et al., 2007). In this study, it was used Midazolam (anxiolytic and muscle relaxant) and Acepromazine (sedative and tranquilizer) in premedication. Despite the lack of analgesic properties these drugs alter reactions to pain by reducing anxiety (Rankin, 2002). Both premedication and the addition of benzodiazepines to anesthetic induction protocol often reduce the dose requirement of Propofol and inhalant anesthetic (Mama, 2013).

In all cases was administered an opioid drug in the perioperative period – methadone initially, which was continued with oral tramadol for 7 days, after discharge. Opioids are indicated for acute and severe pain control in veterinary medicine, and are the mainstay of therapy in the perioperative period (Benson, 2002; Vedpathak et al., 2009). They help to reduce pain response, decrease dose requirements of tranquilizers and decrease dose requirements of anesthetics for anesthetic induction and maintenance (Rankin, 2002; Hellyer et al., 2007). The NSAID Carprofen was used to decrease the inflammation from the surgical trauma, as part of the multimodal pain management strategy (Fox & Johnston, 1997; Vedpathak et al., 2009).

Additionally, it was used cryotherapy in the immediate postoperative period, as it causes peripheral vasoconstriction (and subsequent reduced blood flow) and slows down local inflammation, being indicated 5 to 10 minutes for 3 to 6 times daily (Sawaya, 2007).

Studies show that a high percentage of clean, orthopaedic procedures have some degree of intraoperative contamination, despite the rigid and uniform standards designed to minimize it (Andrade et al., 2016).

Surgical site preparation (preoperative clipping, skin antisepsis and skin preparation) is an important operation-related risk factor that may influence the risk of SWI (Laitinen-Vapaavuori, 2016). Regarding preoperative skin antisepsis, the skin scrub solution used in this study was povidone-iodine 10% dermic solution (EGREMA) diluted 50% with water. PVI is a safe and effective broad spectrum antimicrobial soap, active against gram-positive and gram-negative bacteria as well as fungi, viruses and some spores but has the disadvantage of requiring minimum of 2 minutes of skin contact (Fossum, 2013). Although both PVI and chlorhexidine, another skin scrub solution, endure broad-spectrum antimicrobial activity, in a recent meta-analysis of human studies, it was concluded that preoperative skin cleansing with chlorhexidine should be used preferentially for preoperative antisepsis in clean-contaminated surgery as the overall rate of SWI is lower with chlorohexidine (Noorani et al., 2010). Despite this being true for human surgery, in veterinary surgery such recommendation remains controversial. This superior clinical protection provided by chlorhexidine is probably related to its more rapid action, persistent activity despite exposure to bodily fluids and residual effect (Darouiche et al., 2010).

Antimicrobial prophylaxis is recommended and is one important aspect in orthopaedic surgery (Yeap et al., 2006; Findji, 2014). Antibiotics should be administered IV, 30 to 60 minutes before the first incision, to ensure optimal serum levels of antibiotic at time of surgery (Bratzler & Houck, 2004; Weese & Halling, 2006; Fossum, 2013), readministered every 90 minutes until surgery is finished and discontinued at the end of surgery or a few hours later (Findji, 2014). When selecting an antimicrobial for prophylaxis, we should take into account the microorganisms of concern in a clean orthopaedic surgery (mainly of cutaneous origin *Staphylococcus spp.*, coagulase-negative staphylococci and *Staphylococcus aureus*) (Andrade et al., 2016). Ceftriaxone, a third-generation cephalosporin, was the antibiotic of choice in HVO because it provides satisfactory antimicrobial activity against β-Lactamase resistant bacteria, has potent activity against gram- -negative and gram-positive bacteria (Rebuelto et al., 2002) and achieves high concentration in soft tissue and bone (Papaioannou, Kalivas, Kalavritinos, &

Tsourvakas, 1994). Studies have shown that prophylactic antibiotics reduce the risk of infection when orthopaedic implants are used (Yeap et al., 2006) and prolonging the series of administration for a few hours (≤24h) after surgery is sometimes recommended (Findji, 2014). In this study, patients were discharged from the hospital with Cefalexin (Cephacare, Hifarmax), dosage 20 mg/kg, two times daily for 7 days because it was the surgeon’s choice to prescribe prophylactic antibiotic therapy, due to the experimental nature of the procedure, in order to reduce the risk of postoperative SWI.

Hand disinfection prior to dressing and gloving was done with Desinclor, chlorhexidine soap 0,8%, and Sterillium Gel, an alcohol-based hand gel containing 85% ethanol, which has a unique spectrum of antimicrobial activity (Kampf, Rudolf, Labadie & Barrett, 2002). Studies have shown that Sterillium Gel has a unique bactericidal efficacy (amongst others, *Staphylococcus aureus*) under practical conditions and excellent acceptance by healthcare workers, which may significantly improve compliance for hand hygiene and thereby help to reduce the incidence of nosocomial infection (Kampf et al., 2002). Studies report that Sterillium Gel was able to fulfil the efficacy requirements with 3ml applied over 30 seconds (Kampf et al., 2002; Michelsen, 2008).

Studies show that the use of disposable, single-use materials has been associated with superior barrier properties, particularly with respect to fluid absorption, and in preventing SWIs (Baines, 1996). A study performed in a human hospital found that single-use gowns and drape sets provide the highest cost/benefit rates (Baykasoğlu, Dereli, & Yilankirkan, 2009). In this study, reusable gowns and draping materials were used, which we identified as a potential risk factor that may have increased the risk of postoperative infection, and this fact itself could justify one observed case of postoperative infection.

Surgeons have the highest risk of contact with patients’ blood and body fluids, and breaches in gloving material may expose operating room staff to risk of infections and potentially increase the risk for SWIs (Thomas, Agarwal & Mehta, 2001). The risk of glove breach is higher in orthopaedic surgery due to the nature of the procedures and the use of sharps (Chan, Singh, Oun, & Se To, 2006).
Therefore, as the majority of glove perforations go unnoticed, to reduce the risk of glove breach and consequently reduce the risk of transmission between patient and surgeon, double gloving or orthopaedic reinforced gloves are recommended (Webb & Pentlow, 1993; Thomas et al., 2001; Chan et al., 2006; Hayes et al., 2016). Nor double gloving or orthopaedic reinforced

gloves were used in this study, thus, we identified this as a potential risk factor, that may have increased the risk of postoperative infection, and this fact itself could justify one observed case of postoperative infection.

This study registered a SWI rate of 14% of SWI (1/7 patients) confirmed by bacterial culture, a higher rate than what was previously reported for clean-wounds, about 5.1% to 5.8% (Vasseur et al., 1988; Eugster et al., 2004). These results, as previously mentioned, are most likely related with the higher risk of infection associated with the use of reusable gowns, reusable draping materials and single gloving. Less likely, they can be associated with preoperative skin antisepsis performed with PVI. Although PVI is a safe and effective broad spectrum antimicrobial soap, when compared to chlorhexidine, studies report that the overall rate of SWI is lower with chlorohexidine (Noorani et al., 2010).

The duration of anesthesia is a more significant risk factor for wound infection than the duration of surgery (Beal et al., 2000; Eugster et al., 2004). To decrease the incidence of postoperative wound infection, the duration of anesthesia should be minimized by not prolonging unnecessary surgical time, and auxiliary diagnostic tests, while under anesthesia, should be kept to a minimum (Beal et al., 2000). Additionally, surgical time (>90 minutes) is associated with a higher infection risk (Vasseur et al., 1988; Brown et al., 1997; Eugster et al., 2004; Owen et al., 2009).

Our records show that mean surgical time for Extra-articular iliofemoral suture placement with bone anchors was 40 minutes, which makes it a rapid procedure for coxofemoral luxation repair and a valuable surgical option in order to minimize infections.

Regarding the surgical technique itself, the extra-articular stabilization suture is a practical technique because it is easily performed and a second surgery is not required to remove implants, requires minimal postoperative care and does not require external coaptation. Prolonged and rigid immobilization of a joint has been recognized to be deleterious to periarticular tissues and articular cartilage, inducing proliferation of pericapsular connective tissue, capsular and pericapsular contracture, and major cartilage and subchondral bone alteration (Bojrab & Monnet, 2010). Thus, another advantage of this technique, is that no immobilization period was required after surgery and patients were allowed to put weight on the affected hindlimb immediately after surgery.

However, the overall complication rate was 29% (2/7 patients), higher than what has been previously published for other extra-articular techniques that recorded 0% of postoperative complications (Martini et al., 2001). These results may be associated with poor case selection in this study: case 2 due to lack of owner compliance and presence of concurrent fractures of the left tibia and left radius and case 6 due to the chronicity of the luxation (21 days) and considerable muscle atrophy.

Case 2 was not interventioned again and case 6 underwent amputation, due to the surgeon's preference and poor prognosis in maintaining a functional limb.

We can speculate that, with the results of this study, this technique is not applicable in polytraumatized patients with concomitant injuries to other limbs and chronic luxations. However, small breed and lean dogs with acute luxations and no concomitant injuries to other limbs presented excellent results. During the postoperative period, we observed an early return to limb function in the affected hindlimb and a quick return to normal gait. At final evaluation (8 weeks postoperatively), five out of seven patients (71%) demonstrated full recovery of limb function, which is consistent with an excellent outcome according to Mehl's scoring system.

4 – CONCLUSION

Studies show that there is no ideal surgical technique for the treatment for coxofemoral luxations in dogs, as almost every surgical procedure has complications and drawbacks associated.

In this study, we described an extra – articular iliofemoral suture placement technique with bone anchors and a crimping system. It consists of a iliofemoral suture fixed using two anchor points, maintaining abduction of the femur and internal rotation of the femoral head within the acetabulum.

Although the overall complication rate was 29%, all being reluxation and one case with both reluxation and surgical wound infection, 71% of the patients recovered completely before the postoperative day 30, allowing early weight-bearing of the affected limb.

This technique is a simple and effective method for treating craniodorsal coxofemoral luxations in dogs, being adequate to support the femoral head within the acetabulum and avoids iatrogenic damage of the articular cartilage. This technique does not require the use of immobilization in the postoperative period and it does not require a second surgical intervention to remove the implants.

Although the results obtained were from a limited amount of cases, this modified technique for open reduction of craniodorsal coxofemoral luxation seems to be interesting to address in further studies.

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